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BINAURAL SUMMATION—A CENTURY OF INVESTIGATION*

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The consideration of binaural hearing in general texts is very often limited to the phenomena of localization and binaural beats. A much neglected aspect of this topic is the ability of the binaural apparatus to summate stimuli that are introduced simultaneously in both ears. This review attempts to summarize experiments of the last hundred years that have revealed evidence for or against such binaural summation. Most of the evidence comes from the comparison or contrast of binaural and monaural sensitivity.

A discussion of the investigations of binaural summation during the past century will be facilitated by dividing the field into two distinct areas. Many observations indicate that a definitely supraliminal auditory stimulus sounds louder when heard with two ears than with only one ear; this phenomenon will be referred to as *binaural summation of loudness*. Other observations demonstrate that in order to produce a threshold judgment an auditory stimulus does not need to be so intense when presented binaurally as it does when it is presented monaurally. *Binaural summation at threshold* refers to these indications that the absolute binaural threshold is lower than the absolute monaural threshold.

Experiments dealing exclusively with binaural summation did not come into the literature until about 1930. Before that time the topic of binaural summation was buried in the experiments on binaural localization and binaural beats. This makes it virtually impracticable to review all the experiments relevant to binaural summation, but enough of these studies will be reported to give the reader an impression of a continuous trend in the thinking on this subject.

Experiments on binaural localization and beats conducted in the nineteenth century have already been reviewed by Rostosky (27) and

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Melati (23). Both these reviewers, however, smother the issues of binaural summation beneath the then (ca. 1900) more interesting and general topics of beats and localization.

Binaural Summation of Loudness

It was just a century ago that Seebeck (28) in an experiment on the observation of binaural beats, reported that a given amount of sound from his siren seemed louder to two ears than to only one. He mounted two disks with holes punched at equal distances around their peripheries on an axle which was placed behind the observer's head. A stream of air was directed against each of the spinning disks and the sound produced was led from each disk through a tube to each of the ears. For monaural listening one of the air streams was shut off. If the tubes leading from the disks to the ears were equal in length the sounds stimulating the two ears were assumed to be in phase. Seebeck could, however, change the length of one of the tubes so that the sounds stimulating the ears were 180° out of phase. He observed that a sound heard binaurally was always louder than the same sound heard monaurally, whether the sounds stimulating the two ears were in phase or 180° out of phase. If there is a difference between the two binaural cases, said Seebeck, it is certainly difficult to observe.

Although Mach (22) confirmed Seebeck's observation that a tone sounds louder to two ears than to one, he pointed out that the sound heard binaurally seemed louder when the stimuli presented to the two ears were in phase than when they were 180° out of phase. In his experiment the sound from a tuning fork was fed to three rubber tubes. Tubes *a* and *b*, leading to the left ear, were equal respectively to one and one-half wave-length. Tube *c*, leading to the right ear, was equal to one wave-length. The sound fed through tubes *a* and *c* seemed louder than the sound fed through tubes *b* and *c* (i.e., tones in phase sounded louder than tones out of phase), and both of these combinations sounded louder than the sound fed through all three tubes (actually right ear only since tubes *a* and *b* together would cancel the sound for the left ear).

An early attempt to quantify the increase in loudness which is accomplished in binaural listening was made by Docq (7) in 1870. Here we find one of the early considerations of the advantages of an anechoic (without echo) experimental site. Docq carefully described " . . . a garden whose horizontal surface was covered with grass which reduced reflected sound by scattering the incident waves" (7, p. 19). The sound source was a large clock which could be moved back and forth in front of the observer. Docq equated the loudness of the clock-ticks heard

with one ear to the loudness of the clock-ticks heard with two ears by moving the clock back and forth. He found that the ratio of distances for two ears to distances for one ear was about two to one. That is to say, in order to evoke judgments of equal loudness, the clock had to be twice as distant from the observer listening with two ears as it was when he listened with one ear. Further observations with different sound sources such as a music box, violin, and organ pipes resulted in ratios that were greater than two to one. The procedure for listening with one ear was simply to place the finger in the meatus of the opposite ear.

Docq suggested some possible explanations for the decreased loudness in monaural listening or, as he put it, for the fact that the auditory capacity of the two ears functioning together is more than double the capacity of one ear functioning alone. First, he suggested that the presence of a finger in one ear might cause malfunctioning. Second, he felt that the action of a single auditory nerve was incomplete and abnormal and that this abnormality was reflected back to the other ear, making it function less efficiently. Although Docq's observations have been recorded in several secondary sources, his explanations seem never to have been taken very seriously.

In noting analogues to binocular vision, Fechner (8) reported that stopping up one ear with a finger decreases the total loudness, and also that greater loudness results if two forks of the same pitch are sounded, one beside each ear, than when one alone is sounded. His notion of the excitations from the two ears combining to give one total impression will be considered later.

In the period of time between these observations of Seebeck, Mach, Fechner, and Docq, and the important second volume of Stumpf's *Tonpsychologie* (31) of 1890, there appear to be no further considerations of a supraliminal interaural intensification (*Verstärkung*) although we find in this period observations on the relation of binaural to monaural thresholds, observations which will occupy us presently.

Carl Stumpf had great influence on his students and his conclusions in this matter of binaural summation remained unchallenged for many years. With regard to the greater loudness experienced in binaural listening Stumpf suggested that these early observers had allowed themselves to become victims of an illusion. Of course, said Stumpf, we all know that sounds are fuller, clearer and have greater volume (*Tongrösse*) when they are heard with two ears. So, you see, what they *really* heard as an increase in clarity, fullness, and volume, they *thought* they heard as an increase in loudness.

There seems to be a great temporal gap, after 1890, in studies on

binaural vs. monaural loudness. The next experiment was not until 1929 when Békésy (1) equated in loudness a tone led to one ear with a pair of tones led to two ears. When the two tones heard binaurally were of the same frequency, perfect summation was observed; i.e., the intensity of the single tone was twice the intensity of each of the binaurally presented tones when the observer equated loudness. As the two tones presented binaurally became disparate in frequency the summation decreased. These observations corroborate by analogy some earlier observations by Bloch (2) on binaural summation at threshold.

In 1933, Fletcher and Munson (9) reported data on the difference in the loudness level* at which tones heard monaurally and binaurally sound equally loud. Three frequencies were tested: 125, 1000, and 4000 cps. The difference in loudness level at which the two tones, one heard monaurally and one binaurally, sounded equally loud varied as a function of the loudness level of the tone heard monaurally. A tone in one ear at 108 db loudness level sounds equal in loudness to a tone of 100 db loudness level in two ears. A monaural loudness level of 72 db sounds equal in loudness to a binaural loudness level of 60 db. A monaural loudness level of 25 db sounds equal in loudness to a binaural loudness level of 20 db. If the curve is extrapolated to threshold, we find a difference of 3 db between the monaural and binaural thresholds.

Fletcher and Munson held that the loudness of a tone presented to two ears is just twice the loudness of the same tone presented to only one ear. Churcher (6) argued that this loudness relation of Fletcher and Munson gave support to a nerve-impulse theory of hearing. With twice as many neural impulses set up, the loudness would be twice as great, he said.

Indeed we find certain confirmation of this psycho-neural relation in the experiments of Kemp and Robinson (16). These experimenters observed that the electrical response in either lateral lemniscus at the midbrain level was just twice as great when two ears were stimulated by a tone as when only one ear was stimulated by the same tone. According to these authors, there is little or no interaction between the ears, at least up to the midbrain level. Twice the electrical response and twice the loudness for binaural stimulation suggests a system that has two fairly independent feeders.

More recent data of Caussé and Chavasse (5) are somewhat at variance with the data of Fletcher and Munson. Caussé and Chavasse had their subjects adjust the intensity of a tone presented binaurally until

* The loudness level of a tone is defined as the intensity level of a 1000-cycle tone that sounds equally loud.

it sounded equal in loudness to a tone of fixed intensity presented monaurally. Their results indicate that the difference in intensity increases from 3 db at threshold to a maximum of 6 db at a sensation level of 35 db. From 35 to 60 db the difference remains constant.

To recapitulate, these studies on the difference between the loudness of a sound heard binaurally and the loudness of the sound heard monaurally indicate quasi-unanimity with regard to the existence of some increase in loudness as a result of adding a second ear to the listening system. The sole objector has been Stumpf who insisted that it is not loudness that is being judged when a difference between one and two ears is reported. Precise quantification of the difference between binaural and monaural loudness has not yet been made.

Binaural Summation at Threshold

One of the earliest observations on binaural summation at threshold was made by LeRoux (**20**) in 1875. He reported to his medical colleagues that the addition of a supraliminal sound to one ear would make a formerly subliminal sound in the opposite ear audible. He demonstrated this effect with two tuning forks, large enough not to attenuate too rapidly. First, he struck one and held it to one ear until the sound decayed just below threshold. Then he struck the other fork and held it up to the opposite ear. The addition of this supraliminal sound in the opposite ear made the first fork again audible

We find an early report on the binaural threshold in a paper written in 1878 to show how the then new Bell telephone could be used to listen to nerve and muscle action currents. Tarchanow (**32**) wrote as follows: "I had made these observations with one telephone until I learned that our brain contains the capacity to summate tonal stimuli that are impressed on both ears and in this way to bring about louder tonal sensation" (**32**, p. 354). Although he speaks of "louder tonal sensations," his observations verifying this statement were made at threshold. Tarchanow used a *DuBois-Reymond'schen Schlitten-Apparat* (which seems to be a precursor of the Wagner and Neef hammers, both of which are prototypes of the electric doorbell) to induce voltages in an induction coil which was connected to a telephone. He weakened the intensity in one earphone until it was no longer heard. Then he brought the intensity in the opposite earphone up to the same (subliminal) level and noted that the sound was again heard and localized in the middle of the head. "We perceive the tone in consciousness as going out from this median point, and thus it seems more intense" (**32**, p. 354). In addition to this threshold observation, Tarchanow noted that supraliminal

sounds heard with two ears sounded louder than the same sounds heard in only one ear. He noted further that the two sounds had to be of the same intensity and frequency in order to summate. In support of this generalization he reported that persons with unilateral hearing loss do not show this summation but rather hear the sound always in their good ear. What he meant by "the same intensity" was the same subjective intensity or loudness. This requirement of equated loudness or equal sensation level for binaural threshold summation has been shown recently to be quite correct (3, 29), but the necessity for the two tones to have the same frequency does not seem to hold. Apparently Tarchanow was the first to suggest that there must be some kind of central summating mechanism.

We find two direct confirmations of Tarchanow's results in the following year (1879). Preyer (25) and Körting (19), using essentially the same apparatus, confirmed (still without quantification) the observation that a sound which is just too weak to be heard monaurally can be heard binaurally. In addition to reporting his observations, Preyer joined Tarchanow in proposing some kind of summation in the brain.

In 1883, Fechner (26) insisted that the Tarchanow-Preyer proposal of central summation could not be accepted until an experiment could be devised whereby two sound sources would yield a greater sensation when they are separated, one to each ear, than when they are sounded together, both to one ear. This argument will come up again when we discuss Stumpf and von Hornbostel, both of whom repeated it. Further Fechner pointed out that a mixing (*Mischung*) of auditory nerves in the brain had not yet been shown, even though a binaurally heard tone produces one, not two, perceptions. He suggested that the auditory nerves may have separate endings and also some weak connection (*schwache Verbindung*) that might enhance the unitary perception.

Urbantschitsch (33) presumably demonstrated further the effect of monaural stimulation on the sensitivity of the contralateral ear. He found that practice in judging thresholds with one ear lowers the threshold in the other ear. Stumpf (31) doubted that hearing had been made more acute, but he was quick to point out that attention and concentration may have been enhanced by practice.

Stumpf (31) had other more important things to say about the lowering of the threshold in binaural hearing. First of all, he reported that he could not repeat the Tarchanow-Preyer observations at threshold: " . . . whenever we believed that we heard a sound binaurally . . . it could be shown that it was already audible with one ear" (31, p. 439). This sound which could also be heard with one ear was the sound pro-

duced by both forks. Fechner (**26**) put forth the same argument in 1883. Stumpf could not see the necessity for proposing some kind of central summation when the evidence was merely the fact that *two* forks (one to each ear) sounded louder or could be heard with smaller intensity than *one* (at either ear). He made the observation that Fechner had suggested and used both of the forks in the monaural observation as well as the binaural. Stumpf argued that the intensity in both cases is the same. If he argued thus he must have assumed that there is a central mechanism which makes the divided intensity look like the same whole intensity; yet he actually uses this argument to deny that any central mechanism need be invoked.

Three years later (1893) Urbantschitsch (**34**) took issue with Stumpf on the basis of carefully controlled observations. Urbantschitsch used telephones which were driven by a Neef's hammer and an induction coil. With a meter in the primary coil he could calculate the intensity of the current through the phone. He found that in monaural listening this current had to be approximately twice the amount needed in binaural listening for a just noticeable sensation. A further observation (cf. Tarchanow, **32**) was that this ratio of currents held only in the case of persons who had equally acute hearing in both ears. In persons with unilateral hearing loss, Urbantschitsch did not find this summation. On the other hand, if he compensated for the difference in hearing by plugging the better ear, then indeed the summation was observed. (This was what Shaw, Newman and Hirsh believed in 1947 was their "novel" technique.) Another important qualification, according to Urbantschitsch, was that the two tones should have the same pitch. This requirement has not been confirmed.

In the same year, Bloch (**2**) confirmed the observations of Urbantschitsch and agreed with him that a central summation must take place. He disagreed, however, with Urbantschitsch's requirement that the tones led to both ears must be of the same pitch. Bloch showed that when the two tones were of the same frequency the ratio of currents for monaural and binaural thresholds was maximum. The magnitude of the ratio decreased as the interval between the frequencies of the two tones increased (cf. Békésy, **1**).

The next two decades seem to contain no new investigations of either binaural summation of loudness or binaural summation at threshold. Both Rostosky (**27**) and Melati (**23**) published excellent historical reviews in their papers on binaural hearing. We find their reports on binaural summation, however, couched in a context of binaural beats and not suitably drawn together for present purposes.

In 1919, another argument was brought to bear on the Stumpfian view that binaural summation is no more than the normal, mechanical summation. Klemm (18), using electro-magnetically driven tuning forks, measured the current necessary to drive the forks for both monaural and binaural thresholds. His measures show a ratio that is clearly larger than the ratios of Urbantschitsch (34) and Bloch (2). The ratio of the tuning fork amplitudes for monaural and binaural thresholds was four to one. Since mechanical summation would predict only a two-to-one ratio, Klemm argued, there must be some kind of sensory interaction. "Sensory interaction consists in the enhancement of the excitability of one ear by excitation of the other, especially for sounds near threshold" (Klemm, 18, p. 75).

In 1923, von Hornbostel (35) lined himself up on the Stumpfian side of the argument of the physical vs. the more-than-physical summation. He used a single fork which introduced the sound into a rubber tube. The tube was bifurcated, one branch going to one ear and the other branch to the other ear. He observed that when the sound of the fork decayed enough not to be heard in one ear, it again became audible if the second tube was brought up to the opposite ear. Von Hornbostel (35) observed further that if both tubes were brought to the same ear the sound was also audible, and that therefore the summation was no more than physical. On the use of underwater direction-finding apparatus he wrote, "I have often compared monaural with binaural thresholds and have never found a difference" (35, p. 85).

Wittman (36) made observations on a large number of normal and hard-of-hearing people. These studies primarily concerned auditory localization but we find the following remark on binaural summation:

> . . . the intensity of a binaurally heard sound impression is greater than the monaural impression. If two binaural stimuli are near or under the threshold for monaural hearing, together they will give a distinct sound perception, whereas the monaural would either be perceived weakly or not at all (36, p. 90).

The paucity of material between the 1890's and 1920's is evident in the chapter by Gildemeister (11) in Bethe's *Handbuch*. His chapter on the thresholds and limits of hearing contains a small section on binaural hearing. There he referred to Stumpf (31) and to von Hornbostel (35) as not being able to confirm the earlier observations on binaural summation at threshold. But he also referred to Wittman (36) who sits on the other side of the fence. Gildemeister did not take sides.

The report of Gage (10) in 1932 is apparently the first that is concerned entirely with binaural summation at threshold. It is also the first experiment on the binaural threshold to enjoy the use of vacuum

tubes. Gage applied the output of a beat-frequency oscillator to a loudspeaker which was mounted in a heavily damped box. A rubber tube was led out of the box to an acoustic filter and was then bifurcated. Each branch could be shut off by a clamp. In this way Gage could control the intensity in one or both branches and could compare the binaural with the monaural thresholds. Averaging the results of observations on 22 frequencies between 120 and 800 cps, he stated that the binaural threshold was 1.0 db lower than the better (lower) monaural threshold, and 5.6 db lower than the worse (higher) monaural threshold.

In the following year Sivian and White (30) reported their measurements on minimum audible fields (M.A.F.). These experimenters measured the minimum field required for threshold judgments from observers seated in an anechoic chamber. Sound was introduced to the chamber by a loudspeaker which was suspended one meter away from the observer. Monaural measurements were made on 14 ears and binaural measurements on 12 ears. Different subjects were used in these different sets of measurements and directly comparable data on monaural and binaural thresholds are available for only two subjects. "For two members of the group data were available binaurally as well as on each ear separately. These data show no significant difference between the binaural M.A.F. and the best ear M.A.F. Accordingly, for the three others in the group the best ear M.A.F. was taken to be the binaural M.A.F." (30, p. 295). Sivian and White concluded generally that there is no binaural summation. One might just as well call the binaural threshold the threshold of the better ear, they said. The complications in their treatment and acquisition of data in a free field make it extremely difficult to weigh their decision.

A valuable contribution to binaural summation at threshold was an experiment by Hughes (14) in which the effect of a subliminal monaural stimulus on the contralateral monaural threshold was studied. Actually these were binaural threshold measurements. First Hughes found the monaural thresholds for right and left ears. Then, with sounds that were 3, 4, and 5 db below monaural threshold in the left ear, he remeasured the right threshold. The right thresholds were then found to be 3.1, 2.7, and 2.1 db respectively below their original "unaided" thresholds. Hughes argued that since an ideal summating mechanism would satisfy the following condition:

$$(E_1/E_0)_L + (E_1/E_0)_R = 1$$

where E_0 is energy required at threshold and E_1 is some lesser energy, and since the corresponding values from the above observations turn

out to be .99, .94, and .94 respectively, the ear seems to be a good approximation to a perfect summating device.

It is interesting to note that Hughes obtained results of the same order of magnitude with frequencies that were quite different in the two ears, a fact which Urbantschitsch (34) denied, and which contradicted Bloch (2) who had said that the summation decreased as the frequency interval between the sounds in the two ears increased. In a 1940 article, Hughes (15) compared the summation in the ears with physical summation that obtained externally (as Fechner, Stumpf and von Hornbostel had suggested). He led the sound from the two earphones which he had used on both ears to a small, well damped box. In the cases where the two frequencies were different, there was slightly less summation for this monaural threshold than there had been when each of two tones had been led to one or the other ear. The only case in which he found perfect summation in the box was that in which the two sounds were of the same frequency.

In the same paper, Hughes attempted to measure the effect of contralateral and ipsilateral supraliminal stimuli on the monaural threshold. He found that contralateral audible stimuli have little effect at least up to 15 db sensation level. The monaural threshold is raised, however, when the contralateral stimulus is of the same frequency. These observations were actually observations on localization, for "threshold" turned out to be "level for central localization."

As long ago as 1893, Urbantschitsch (34) had shown that binaural summation could not be demonstrated in unilaterally hard-of-hearing persons unless the better ear was plugged and the two ears thus "equated" in sensitivity. Actually, the difference between the two monaural thresholds of so-called normal observers may be appreciable. In 1947, Shaw, Newman, and Hirsh (29) argued that the difference between monaural and binaural thresholds varied as the sensitivities of the two ears were different. Hughes (14) had already shown what course this difference would take as the ears were mismatched.

An "equating procedure" for normal observers was used by Caussé and Chavasse in 1941 (3). These experimenters measured both monaural thresholds very carefully before presenting binaural stimuli. Any difference that was found between the two monaural thresholds was compensated for in the apparatus so that when binaural hearing was accomplished both ears were listening at the same sensation level. Shaw, Newman and Hirsh (29) independently used a similar "equating" procedure, as did Keys (17). Experiments which have utilized an equating procedure are fairly consistent with each other with respect to

the difference between the binaural and the equated monaural threshold. This unanimity is shown in Fig. I, where the difference between the binaural and the equated monaural absolute thresholds is plotted as a function of frequency. Shaw, Newman and Hirsh (29) and Keys (17) have reported that the difference between the binaural and equated monaural thresholds of intelligibility for speech is also approximately 3 db.

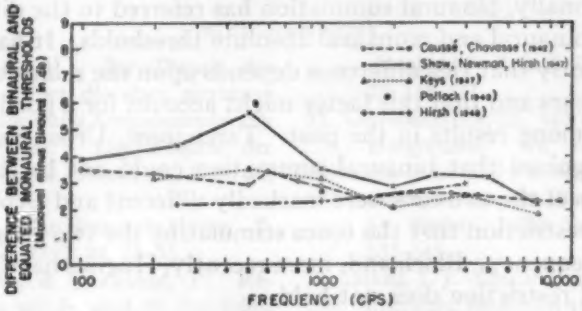

FIG. I. BINAURAL SUMMATION AT THRESHOLD

So far, the review of experiments on binaural summation at threshold has concerned absolute thresholds—thresholds for stimuli presented against a quiet background. More recent work of Hirsh (12, 13) has been concerned with the difference between binaural and monaural masked thresholds—thresholds for stimuli presented against a background of noise. Hirsh has shown that the phase angle between the two earphones for both the noise and the tone is a critical parameter. His results indicate that when the phase angle between the earphones is either 0° or 180° for *both* the tone and the noise the binaural threshold is higher than the monaural: some sort of "interaural inhibition" is observed. This interaural inhibition is most marked in the lower range of frequencies between 200 and 500 cps and the effect increases as the noise is made more intense. When the phase angle for the tone is opposite to that for the noise, interaural (or binaural) summation obtains. This interaural summation is most marked in the same range of frequencies as that in which the interaural inhibition is most marked, and the interaural summation also increases as the noise is made more intense. A corroboration of these results is to be found in the recent work of Licklider (21) on the intelligibility of speech masked by noise.*

* These results of Hirsh and Licklider had been anticipated by observations of Langmuir, Schaefer, Ferguson, and Henelly in "A Study of the Binaural Perception of the Direction of a Sound Source," NDRC Report 6.1-1840 (June 1944) PB 31014.

SUMMARY

That a supraliminal auditory stimulus sounds louder to two ears than to only one has been known since Seebeck made his observations a little over a century ago. Stumpf argued that loudness is not the attribute that increases when the second ear is added to the listening apparatus. Seebeck did not observe any change in binaural loudness when the phase angle between the two ears was changed, but Mach did.

Traditionally, binaural summation has referred to the difference between the binaural and monaural absolute thresholds. It has been suggested recently that this difference depends upon the relative sensitivity of the two ears and that this factor might account for a good part of the disparity among results in the past. Tarchanow, Urbantschitsch, and Bloch recognized that binaural summation could not be shown if the sensitivities of the two ears were markedly different and Urbantschitsch added the restriction that the tones stimulating the two ears must be of the same frequency. Bloch and, more recently, Hughes have shown that this second restriction does not hold.

When the ears of a normal observer are "equated" in sensitivity before binaural listening, the difference between the binaural and the equated monaural thresholds seems to be about 3 db. The variation of this difference as a function of frequency remains to be worked out more precisely.

The simple summative results which obtain when thresholds are measured in the quiet do not apply to thresholds of stimuli which are masked by noise. For certain interaural phase relations between the tone and the masking noise, interaural inhibition may be observed: the binaural threshold is higher than the monaural threshold. For other phase relations, interaural summation (as discussed above) is observed. The adjective *interaural* has recently been introduced to modify both "summation" and "inhibition." *Interaural* suggests an interaction between the ears rather than the independent action of two separate ears suggested by *binaural.*

The experiments which have been reported reveal a considerable amount of evidence on the interaction of the two ears of the human organism. We know that a sound is heard more easily and, once heard, sounds louder when an observer uses two ears than when he uses only one. More than that, we know that the difference in loudness between a tone heard monaurally and a tone heard binaurally varies with intensity. The difference between the binaural and monaural thresholds varies as a function of the frequency of the tonal stimulus and as a function of the level of a background noise against which stimuli are presented.

Explanations which have been deduced by analogy to mechanical or electrical systems have seemed inadequate in the light of subsequent data. It may be hoped that future experimentation will bring to light the parameters which determine interaural summation at threshold and interaural summation of loudness. Only then will we recognize the physiological bases of the phenomena which have been reviewed here and which are yet to be observed.

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COLOR TERMS AND DEFINITIONS

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The list of terms and definitions presented here was abstracted from the new Comparative List of Color Terms compiled by the Color Terms Subcommittee of the Inter-Society Color Council.[1] The aim of that comparative list is to bring together in one place the color terms used by various branches of industry and science, and to show in a logical way the relationships of the terms as defined by the various groups. The present list is intended to include only the terms and usages which are of interest to psychologists.

A strictly psychological definition of color was adopted as the type most likely to be acceptable to psychologists; and then, with this as a basis, numerous existing definitions were revised as necessary and a number of new terms and definitions were added. Warren's *Dictionary of Psychology* was used as an important though partial check list and Harry Helson supplied some essential terms with definitions not to be found there.[2] A Comparative List of Color Terms, based on a survey of terminology by the Problems Committee of the Inter-Society Color Council, also was consulted. This list was compiled by Forrest L. Dimmick and mimeographed at Hobart College in 1939. Quite a few recent definitions by Deane B. Judd of terms relating to defective color vision were adapted and included in the new list. All of the members of the A.P.A. Delegation to the Inter-Society Color Council were asked to suggest desirable terms and definitions. As is quite evident, the scope of the list was not confined strictly to color but includes numerous allied terms having to do with vision and light.

Usages preceded by an asterisk (*) are of a secondary nature in the sense that they probably did not originate with and do not really "belong" to this group, but are still judged to be of sufficient value to warrant inclusion. This distinction between primary and secondary terms is necessarily somewhat arbitrary and uncertain. A dagger (†) indicates terms which were considered obsolete by 1947.

[1] Newhall, S. M., and Brennan, J. G. (Compilers.) *The ISCC comparative list of color terms.* In press.

[2] Warren, H. C., Editor. *Dictionary of psychology.* New York: Houghton-Mifflin, 1934.

Accommodation: Change in shape of the eye-lens as the individual focuses for a different distance. (The curvature increases for nearer focus.)

Achromatic: Lacking in hue and saturation and therefore falling in a series of colors which varies only in lightness or brightness.

Achromatic Color: A visual quality characterized by its degree of brightness or lightness, and exhibiting no hue or saturation. Examples of achromatic colors are gray, black, white, clear, silver.

Achromatic Stimulus: A visual stimulus which characteristically evokes an achromatic color. Syn. Neutral stimulus, Achromatic light.

***Achromatopsia:** Form of monochromatism in which all colors are achromatic. Syn. Achromatism, Total color blindness.

Adaptation: The progressive adjustive changes in sensitivity which regularly accompany continued stimulation of a sense organ. (Cf. visual adaptation.)

Adaptometer: Any device for measuring the temporal course or momentary degree of sensory adaptation, in terms of fall or rise of threshold or sensitivity. (Dark adaptation is commonly measured in terms of the simple light threshold, the adaptometer consisting of a variable, measured light stimulus of low luminance.)

After-Image: A prolongation or renewal of a sensory experience, ascribable to residual excitation after the external stimulus has ceased to operate.

After-Image, Negative: A sensory response which follows another and is dependent upon the prior stimulation, but which is of a quality antagonistic or complementary to the preceding experience. (E.g., a visual after-image in which black and white relations are reversed and the colors are usually approximately complementary to those of the original response.)

After-Image, Positive: A sensory response which follows another in the absence of direct stimulation, and reproduces the qualities of the preceding experience. (Syn. Positive after-sensation. Contrast with: Negative after-image, in which the qualities are reversed, or complementary. But the after-effect following a light pulse is preferably termed a positive after-image if it appears brighter than the surrounding field, and a negative after-image if it appears less bright. In this use, the terms positive and negative refer to brightness only, and not to the hue of the image. Cf. Purkinje after-image, which is positive in brightness and complementary in hue to the primary image.)

Albedo: The whiteness of a matte surface as evaluated in terms of its diffuse reflectance for daylight.

Albedo Perception: The discrimination of surfaces according to their diffuse reflecting power or albedo, regardless of the illumination under which they are seen.

***Amaurosis:** Loss of sight due to defect of the optic nerve, which is not accompanied by any perceptible change in the eye itself.

***Amblyopia:** Dimness of vision for which no organic defect in the refractive system of the eye has been discovered. (Found in total color blindness, in albinism, in toxic conditions, and associated with excessive use of tobacco and various drugs.)

***Angle of Incidence:** The angle between the path of an oncoming ray of light and the normal to the surface on which it impinges.

***Angle of Reflection:** The angle between the path of a ray of light and the normal to the surface from which it is reflected.

***Angle of Refraction:** The angle between the path of a ray of light and the normal to the surface of the medium by which it is refracted.

***Angles of Displacement:** The angles by which the respective eyes deviate from the direction occupied in the primary position. (The vertical displacement is the angle of the eye upward or downward from the primary position; the lateral displacement is the angle to right or left.)

Anomaloscope: The spectral apparatus for the determination of color deficiency by the use of the Rayleigh equation (Nagel).

***Anomalous Trichromatism:** Form of trichromatism in which some of the proportions of colorimetric primaries required to match various colors are beyond normal limits. Anomalous trichromatism may be either protanomaly, deuteranomaly, tritanomaly, or some irregular form.

Attributes of Color: The chromatic colors have the attributes of hue, saturation, and brightness or lightness; but the achromatic colors do not have those of hue and saturation. All colors do have the general attributes of duration and extent, but these are rarely mentioned. (Syn. Dimensions of color.)

Attributes of Sensation: The fundamental, intrinsic characteristics of simple sensory response, generally recognized as quality, intensity, duration, and extensity; clearness or attensity sometimes also being included. (Syn. Dimensions of sensation.)

Aubert-Förster Law: A generalization from the Aubert-Förster phenomenon, namely, that visual acuity for a near object is greater than for a similar distant object, even though the latter is large enough to subtend the same visual angle as the near object.

Aubert-Förster Phenomenon: Small near objects can be recognized over a larger portion of the retina than larger, more distant objects that subtend the same visual angle.

Bezold-Brücke Phenomenon: A hue shift due to change of luminance of chromatic stimuli and independent of wave-length and purity. With increasing luminance, colors around red and green become either yellower or bluer, according to their location in the chromatic cycle.

Binocular Color Mixture: The presentation of different color stimuli to corresponding areas of the two retinas, resulting in a single fused impression. This effect occurs only under special conditions; often the effect is rivalry, especially when the two stimuli are very different in their separate effects.

Binocular Flicker: Flicker evoked by rapidly alternating presentation of stimuli to the right and left eyes, usually in such a manner that the gaps in the stimulus presented to one eye are filled by the stimulus presented to the other.

Binocular Fusion: The combination of two images, falling upon the two retinas, into a single visual impression. The images may be alike, or may differ to some degree in form and color.

Binocular Rivalry: Same as Retinal Rivalry.

Binocular Vision: Vision with the two eyes operating conjointly, usually with fixation of both on the same objective point. In general, characterized by a

single perception of the objects fixated, but in certain conditions by doubling or by rivalry. An important factor in perception of space, giving projection and relief. Contrast with uniocular (or monocular) vision.

Black: An achromatic color of minimum lightness (maximum darkness) which represents one limit of the series of grays, and which is the complement or antagonist of white, the other extreme of the gray series. Though typically a response to zero or minimal stimulation, black appears always to depend upon surrounding contrast.

***Blackbody Radiation:** Radiant energy emitted from a theoretically nonselective incandescent radiator, and having the spectral distribution given by Planck's law, i.e., a distribution determined solely by the temperature of the radiating body.

Blending: A gradual or imperceptible change from one color to another.

Blind Spot: An irregular area in the retina which is not sensitive to light-stimulation because it lacks rods and cones. The blind spot is around 6.5° of visual angle in diameter and is situated about 15° to the nasal side of the center of the retina, corresponding to the place of exit of the optic nerve. The blind spot explains the substantial gap in the temporal side of the monocular visual space. Syn. Mariotte's spot, from its discoverer.

Blue: 1. The hue attribute of visual sensations typically evoked by stimulation of the normal human eye with radiation of wave-length approximately 476 millimicrons. 2. Any hue predominantly similar to that of the typical blue. The complement of yellow.

Blue Arc Phenomenon: The pair of luminous blue or purple arcs which sometimes appear to the practiced observer as connecting a somewhat decentered stimulus object with the projected locus of the blind spot. The phenomenon is attributed to secondary stimulation of retinal receptors lying along the course of the originally excited nerve fibers.

Blue-Sighted: Displaying a heightened color sensitivity (congenital or acquired) for blue.

Blue-Yellow Blindness: A rare type of partial color blindness, or dichromasy, in which blue and yellow stimuli are confused because the color gamut is reduced to reds, greens, and grays. Cf. Tetartanopia and Tritanopia.

Bright: Characterized by a relatively high degree of brightness.

Brightness: That attribute of a film color or an illuminant color by reference to which it can be classed as equivalent to a member of the achromatic series ranging from very dim to very bright. For convenience in general discussion, brightness is sometimes generalized to cover the related term lightness.

Brightness Contrast: A change in brightness in a given area of the visual field, due to very recent stimulation (in respect to luminance) of an adjoining or neighboring area, or of the given area.

Brightness Threshold, Absolute: The intensity of the least visual stimulus (of any specified wave-length composition) sufficient to evoke a brightness in excess of that of the adjacent unstimulated visual field. The value is determined after complete dark adaptation but does not exclude the effect of processes normally active in the sense-organ.

†Brilliance: That attribute of any color or visual sense-quality in respect to

which it may be classed as equivalent to some member of a series of grays ranging from black to white. Distinguish from brightness, which has reference solely to stimulus-magnitude.

Bulky Color: Same as Volume Color.

Campimeter: An instrument with a flat chart for mapping the sensibility of the retinal field. In the campimeter, equal visual angles are represented by greater lengths as the distance from the fixation point increases, in accordance with the tangent function; contrasted with the perimeter in which the instrumental determinations are proportional to the visual angles.

***Candle:** The unit of luminous intensity of a source of light. The international candle, agreed upon in 1909, is reproduced from any one of a number of carefully intercompared standard incandescent lamps, operated and used under specified conditions; the German Hefnerkerze (Hefner candle) is about 0.9 international candle. Cf. Candle, New.

***Candle, New:** As from January 1, 1948, the unit of luminous intensity will be such that the luminance of a complete radiator at the temperature of solidification of platinum shall be 60 units of intensity per square centimeter. Resolution of the Comité International des Poids et Mesures, Paris, June 1937.

Charpentier's Bands: A series of alternating light and dark bands which follow a moving slit-shaped stimulus presented against a dark visual field and which are due to fluctuations of visual excitation similar to those which give rise to after-images.

Chroma: The dimension of the Munsell system of color which corresponds most closely to saturation.

***Chromatic Aberration:** In an optical system, the failure of rays of light from a given point to come to a focus at a point, owing to the fact that light from different parts of the spectrum is refracted unequally.

Chromatic Adaptation: The change in chromatic sensitivity, manifest in alteration of hue or saturation (or both), which is dependent on continued chromatic stimulation.

Chromatic Color: A color, or visual quality, which manifests hue and saturation, and therefore cannot be placed in an achromatic series.

Chromatic Contrast: A change in hue or saturation (or both) in a given area of the visual field, due to the concomitant state of chromatic stimulation of an adjoining or neighboring area, or of the given area or its neighborhood at a closely preceding time.

Chromatic Flicker: A pulsating or flicker phenomenon, due to differences in either dominant wave-length or purity, or both, between stimuli of equal luminance, which are alternately applied to the same retinal area. Distinguished from flicker in general, which may involve also pulsations in brightness.

Chromatic Valence: A relative measure of the chromaticness-producing power of a chromatic stimulus, as evident in additive color mixture. When chromatic stimuli are mixed in such proportions as to yield gray they are said to be equated in chromatic valence. When spectrum stimuli are equated in luminance they vary markedly in chromatic valence.

***Chromaticity:** The aspect of the color stimulus which is specified by dominant wave-length and purity (alternatively, complementary wave-length and purity) taken together.

***Chromaticity Diagram:** A plane diagram, each point in which represents a different combination of dominant wave-length and purity, and which is usually constructed in some form of triangle with colorimetric primaries represented at the corners. The ICI standard chromaticity diagram is essentially a right triangle representing hypothetical primaries and the complete chromaticity gamut of the ICI standard observer.

Chromaticness: The aspect of a color which is specified by hue and saturation taken together.

***Chromatopsia:** An abnormal state of vision in which colorless objects appear colored, e.g., yellow after santonin, red after snow-blindness.

***Chromesthesia:** Synthesia of the type in which colors accompany auditory stimuli. Also called colored hearing.

Color: A sensory or perceptual component of visual experience typically characterized by the attributes of brightness or lightness, hue, and saturation; but in certain cases having zero saturation and so no hue. Sometimes, however, the term is limited to those experiences which exhibit hue, as distinguished from the members of achromatic series.

***Colorants:** Substances which are used to produce color stimulus objects, such as dyes and pigments.

Color Attribute: Hue, brightness or lightness, and saturation are the primary color attributes or color qualities. Also called color dimension.

Color Blindness: A significant defect of color vision, usually congential, and marked by a partial (dichromatism) or a total (monochromatism) loss of hue discrimination.

Color Circle: The closed, finite system of hues, including red, orange, yellow, green, cyan, blue, purple, and magenta, which is characteristic of trichromatic vision. Also called color cycle.

Color Constancy: The relative independence of object colors of changes in illumination or of other viewing conditions.

Color Conversion: Change in any dimension of color due to change in the conditions of viewing.

***Color Deficiency:** A general term for all forms of color vision which yield chromaticity-discrimination below normal limits. Includes monochromatism, dichromatism, and anomalous trichromatism.

Colored Hearing: A form of synesthesia that is manifested by the subjective occurrence of colors when certain sounds are heard. Usually a given color or shape will be associated with some specific auditory quality.

Colored Shadow Phenomenon: An accentuated type of simultaneous contrast observed when two shadows are cast upon the same surface near each other by two lights of different color; when the shadows are made about equal, each one tends strongly to appear of a color complementary to that of the light which casts it, the general surface appearing of an indifferent color. In case one of the lights is white, or achromatic, the shadow it casts

is strongly of the color of the other light; a very moderate color-difference between the lights is usually sufficient.

Colorimeter: A color-matching instrument for equating a known color stimulus mixture to an unknown color stimulus, so that the latter is specified in terms of the former. The colorimeter may be calibrated, or the specification may be transformed, to yield a measurement in terms of some standard system of colorimetry.

Colorimetric Primaries: Any three color stimuli which correspond to the corners of a color triangle or are additively mixed to match an unknown color when making a colorimetric measurement. Representative red, green, and blue stimuli are most commonly used as colorimetric primaries; but theoretically any three color stimuli can be used if the color from no one can be matched by the color from the other two.

Color Mixture: The presentation of two or more color stimuli to the same area of the retina effectively at the same time for the purpose of eliciting their combined effect. Mixture may be accomplished in various ways such as simultaneous projection, rapid alternation, or diffusive combination of the several stimuli concerned.

***Color Mixture Data:** The amounts of the colorimetric primaries required to afford a match, at a photopic level of luminance, with an appropriately illuminated color sample.

Color Sensation: Any elementary visual experience of a chromatic or achromatic nature which results from stimulation of the retina, as distinguished from the physical considerations descriptive of the stimulus. More narrowly, those elementary visual experiences which exhibit hue.

Color Shades: Colors of brightnesses or lightnesses which are darker than median gray. Contrast with tint.

Color Solid: A symbolic figure in three dimensions, which represents the relations of all possible colors with respect to their primary attributes of brightness or lightness and saturation. Usually brightness appears as the vertical axis of the figure, with hue and saturation represented in polar coordinates about the brightness axis, saturation being radial. The boundaries of the solid are actually irregular, but it is sometimes represented as a cylinder, a sphere, a spindle or a double pyramid with a common (square) base.

Color Stimulus: Radiant energy of any degree, wave-length, or composition within the ranges which are capable of adequate stimulation of retinal receptors. The term is sometimes limited to adequate stimuli for hueful responses. Color stimuli are sometimes specified in the psychophysical terms of luminance, dominant wave-length, and purity.

†**Color Surface:** A plane section of the solid schematic figure that represents all possible color experiences, usually taken perpendicular to the axis of brightness variation, and representing all possible hues and saturations at a single level. Cf. Color Triangle.

***Color Temperature:** The temperature of a blackbody or complete radiator at which it yields a color matching that of a given sample or radiant energy. The blackbody colors form a single series of relatively unsaturated visual qualities, ranging from red, through orange, white, pale blues, and violets,

as the temperature is increased. The temperature is measured on the absolute or Kelvin scale.

Color Tints: Colors of brightnesses or lightnesses which are lighter than median gray. Contrast with shade.

Color Triangle: This is a chromaticity diagram which is (typically) in the form of an equilateral triangle with apices representing R, G, and B primaries and the enclosed area representing all the chromaticities possible by additive mixture of the primaries. Characteristic of the color triangle is the adjustment of the primary scales so unit amounts will yield an achromatic mixture which is represented by the centroid of the triangle; and the relative amounts of the primaries necessary to yield each chromaticity are then indicated by corresponding distances on the triangle. Also called Maxwell triangle.

Color Vision: Vision with the response of chromatic color.

Color Vision, Theory of: A theory as to the physiological mechanism underlying color phenomena, which is used to explain or coordinate the phenomena in question. Cf. Young-Helmholtz Theory, Hering Theory, Ladd-Franklin Theory, Duplicity Theory, Trireceptor Theory.

***Color Weakness:** A defect in color vision marked by diminished color sensitivity rather than actual loss of any hue. Also called anomalous trichromatism.

Color Zones: Regions of the retina which have different characteristics as to chromatic response. For most individuals and usual conditions, the central portion shows full chromatic response, while red and green responses disappear at a moderately peripheral position, and blue and yellow fail toward the extreme periphery. The exact boundaries of any zone depend upon the extent, intensity, and chromatic power of the stimulus used; they vary also with the individual, and with the technique employed. Also called retinal zones.

Compensation: An effect of adaptation whereby shadows appear less dark and high luminances appear less bright or light.

***Complementary Wave-Length:** The wave-length of the portion of the visible spectrum which, when combined with a color stimulus in suitable proportions, matches the adopted achromatic stimulus, is the complementary wavelength of the color stimulus.

Complements, Complementaries, Complementary Colors: Any pair of chromatic color stimuli which, when mixed additively, give rise to an achromatic color. All three terms are in use. The singular is used for one member of the pair, e.g., yellow is the complement of blue.

Cone, Retinal: A type of minute structure found in the retina of the eye, which constitutes a specific receptor for vision. Distinguish from retinal rods, another visual receptor; the cones are without visual purple and are believed to operate for both chromatic and achromatic (gray) visual qualities at higher levels of stimulation, the rods for achromatic only at low (twilight) levels; the rods and cones form the second layer of the retina from the surface of the eyeball, lying just within the layer of pigmented cells; at the center of the retina the cones are long and slender and closely packed to the exclusion of rods; farther out they are shorter and thicker and interspersed among the more numerous rods, and their outer portion has become small

and cone-shaped, whence their name; it is estimated that there are 7,000,000 cones in the human retina.

Constancy: The phenomenon that perceptual objects retain to a greater or lesser degree normal appearance in relative (though not in absolute) independence of the local stimulus conditions. Applied to the following properties: color—preservation of normal hue, saturation, and brightness under different illumination; form—persistence of the shape of an object when, from geometrical optics, a change might be expected; magnitude—preservation of apparent size in spite of differences in the retinal image.

Constancy Hypothesis: The untenable hypothesis of a one-to-one correspondence between sensory stimulus and response. This hypothesis is opposed to the phenomenon of perceptual constancy, which is the tendency to perceive objects and qualities as they "really are," i.e., as they normally appear to be, rather than as they stimulate the receptor on specific occasions.

Contrast: Intensification or emphasis, by juxtaposition of stimuli, of two contrary or opposing mental data. Contrast may be simultaneous, viz., between simultaneous impressions, or successive, viz., between impressions which closely follow each other.

Contrast Flicker: Flicker which is induced into a physically constant field by a neighboring flicker.

†**Cortical Gray:** A term applied to a median gray, in the theory that gray is a primary color-process due to activity in the cerebral cortex, which appears in the absence of retinal stimulation.

Critical Flicker Frequency: The minimum number of alternations per second of two different visual stimuli (or the frequency of any periodically variable stimulus) upon the same retinal area which will permit a constant effect in visual experience, as if from an invariable stimulus, i.e., which will result in the elimination of flicker. Cf. Flicker.

Cyan: 1. The hue attribute of visual sensations typically evoked by stimulation on the normal human eye with radiation of wave-length approximately 494 millimicrons. 2. Any hue predominantly similar to that of the typical cyan. The complement of red.

*__Daltonism:__ Same as color blindness. So called from John Dalton, 1766–1844, who was himself color blind for red and green and published a description of his case.

Dark: Characterized by a low degree of lightness (relatively high darkness).

Dark Adaptation, Darkness Adaptation: The increased visual sensitivity to light, sometimes manifest in increased brightness of a fixed stimulus, which is dependent on reduction or absence of light stimulation.

Dark-Adapted Eye: An eye whose condition has been so modified by the withdrawal of general light stimulation that faint stimulation has become more effective. Contrast with light-adapted. Cf. Adaptation.

Day-Blindness: A special condition, usually due to impairment (scotoma) of the central area of the retina, in which the individual sees better in dim light. Also called nyctalopia or hemeralopia, which are confused in usage and had best be avoided. Contrast with night-blindness.

Depth Contrast: Contrast between different depth levels as distinguished

from classical contrast which occurs between surfaces at the same depth level.

***Deuteranomalous Trichromat:** An individual having deuteranomalous vision, viz., deuteranomaly.

***Deuteranomaly:** Form of trichromatism in which the luminosity function is within normal limits, but in which an abnormally large proportion of stimulus green is required in a red-green stimulus mixture in order to match a given yellow.

***Deuteranope:** Individual have deuteranopic vision.

***Deuteranopia:** Form of dichromatism in which green and purplish red stimuli are confused, but a normal proportion suffices to match a given yellow, and the luminosity function also is within normal limits. Sometimes called green blindness.

***Dichromat:** Individual having dichromatic vision.

***Dichromatism:** Form of vision yielding colors which require in general two independently adjustable primaries (such as red and green, or blue and yellow) for their duplication by stimulus mixture. Dichromatism may be either protanopia, deuteranopia, tritanopia, or some irregular form such as tetartanopia.

Difference Limen: The small amount of difference between two compared stimuli which gives rise (statistically) to a perceived difference as often as it does not. The difference limen is the same as the average just noticeable difference. Also called differential threshold, threshold of difference.

***Diffusion Circle:** A circle of color in an optical system due to rays emanating from a point source which have not been brought into sharp focus because of chromatic aberration. A diffusion circle is likely to show different hues at different distances from its center. Also called dispersion circle.

Dimensions of Color: Same as attributes of color.

Dimming Effect: An enhancement or rejuvenation of either a chromatic or an achromatic adaptation effect (i.e., an after-image), which is brought about by "dimming" or reducing the luminance of the stimulating field against which the effect is seen. The effect depends upon the degree of dimming.

***Dominant Wave-Length:** The wave-length of that homogeneous spectral light which, when mixed with achromatic light in suitable amounts, will match a given sample color.

Duplicity Theory: The doctrine that visual sensation rests upon two distinct receptoral mechanisms present in the retina, the rod and the cone systems, respectively; the rod systen is supposed to be responsible for vision at low or twilight illumination levels and to yield an achromatic result in consciousness; the cone system is supposed to mediate daylight and complete color vision, but to be inactive under twilight conditions. The theory was formulated by von Kries in 1894.

Emmert's Law: The perceived size of an after-image is directly proportional to the distance from the observer of the plane upon which the after-image is projected.

Episcotister: A disk with adjustable open and closed sectors together with a mechanism for rotating it. Used for adjusting or equating luminances and for the short exposure of visual material, especially in the study of flicker.

***Erythrogenic Radiations:** Long-wave light stimuli which normally give rise to the experience of red. Suggested by Ladd-Franklin to replace the physicists' equivocal term "red."

***Erythropsia:** A type of chromatopsia or colored vision (usually following over-exposure to intense light) in which all objects appear tinged with red. Cf. Snow-Blindness.

Extraspectrum Hue: A hue which is not characteristically evoked by any color stimulus in the spectrum. Extraspectrum hues range from the extreme violet through the series of purples and magentas, and include the psychologically primary red itself.

Fatigue, Retinal: Depletion of the capacity of the retina to respond to light and color stimuli. Postulated to explain negative after-image, successive contrast, etc.

Fatigue, Visual: Decreased ability of visual performance and/or characteristic sensations or feelings resulting from prolonged visual work.

Fechner's Law: The intensity of the sensory response is proportional to the logarithm of the stimulus intensity. The logarithmic relation fails to hold experimentally, but a general principle of diminishing returns seems characteristic of all sensory response.

Fechner's Paradox: If one views a stimulus field binocularly with a moderately light smoked glass covering one eye, the total impression becomes brighter the instant the covered eye is completely occluded. The paradox is the fact that a brighter impression results when the stimulus light is reduced.

Figure: Any group of visual impressions which is perceived as a unit pattern or object.

Film Color: Color seen as a soft, non-substantial, indefinitely localized, and texture-free film, viz., in the film mode of appearance. Examples: colors seen in spectroscopes, or filling apertures, the clear sky, etc.

Flicker, Flicker Phenomenon: A rapid periodic change perceived in a visual impression, due to a corresponding rapid periodic change in the intensity or some other character of the stimulus. Flicker disappears when the frequency of the stimulus-change exceeds a rate called the critical flicker frequency, which is about 25 to 30 cycles per second when each cycle consists of a moderately bright and a wholly dark half-period; the critical rate is somewhat higher at higher intensity-levels and somewhat lower for lower intensities; the rate is lowered with decrease in the intensity-difference between parts of the period.

***Flicker Photometry:** A method of photometry in which two different color stimuli are alternately presented to the eye at a suitable rate; the stimuli are considered equal in luminance when the flicker is at a minimum.

Flight of Colors: The succession of chromatic images which follows an intense momentary stimulus viewed against a dark ground.

***Footcandle:** A unit of illuminance representing the light-flux density incident at a surface each point of which is one foot from a point source of one candle.

***Footlambert:** A unit of luminance equal to the uniform luminance of a perfectly diffusing surface which emits or reflects one lumen per square foot.

Fovea: A small ellipse-shaped depression in the central region of the retina, somewhat less than a degree of visual angle in maximum diameter, and char-

acterized by the sharpest cone vision. The *fovea centralis* is the normal center for visual fixation and attention.

Fundamental Colors: The several hypothetical colors corresponding respectively to the fundamental response processes of color vision theory.

Fundamental Response Curves: The set of three spectral sensitivity or mixture curves (usually plotted with relative luminosity as a function of wave-length) which represent the actual sensitivities of the fundamental response processes, according to tri-receptor theories of color vision. The maxima of these response curves are believed to be about 450, 540, and 590 millimicrons, respectively.

Fundamental Response Processes: The several hypothetical physiological processes, sensitivities, or excitations which are believed to underlie the fundamental colors.

Glitter: Cf. Sparkle.

Glossiness: An attribute of the surface mode of appearance which ranges from matt to maximum. Low glossiness is characteristically evoked by reflection from rough diffusing surfaces and high gloss from smooth surfaces.

Gray: An achromatic color of any lightness intermediate between the extremes of black and white. Gray is typically a response to an achromatic stimulus situation involving contrast.

Green: 1. The hue attribute of visual sensations typically evoked by stimulation of the normal retina with radiation of wave-length approximately 515 millimicrons. 2. Any hue predominantly similar to that of the typical green. The complement of red-purple or magenta.

Ground: The unfocused surroundings and interstices of a figure or object, perceived as lying beyond and not belonging to the figure or object, e.g., the background in a painting. Figure and ground are sometimes reversible, as when an interwoven black-white pattern may appear either as a white figure on a black background, or *vice versa*.

Halo: A narrow bright band which is observed surrounding the dark after-image of a bright stimulus.

Hering After-Image: The first positive after-image, or after-sensation, which occurs following a brief light-stimulus. It is bright and of the same hue as the original sensation.

Hering Grays: A set of 50 neutral gray papers, graded from extreme white to extreme black in steps which approximate subjective equality. The set represents the achromatic series of colors.

Hering Theory of Vision: The theory proposed by E. Hering and modified by later writers, according to which colors are due to three pairs of antagonistic processes in the optic system, one member of each pair being catabolic, the other anabolic, the pairs yielding respectively, white and black, yellow and blue, and red and green. The two members of any one pair of colors are said to be antagonistic colors.

***Heterochromatic Photometry:** Photometry of lights of different chromaticities.

***Holmgren Test:** A test of color blindness which involves the matching of skeins of different-colored yarn with three standard skeins.

***Horner's Law:** A principle of the inheritance of color blindness according to

which the common types are transmitted from males to males through unaffected females.

Horopter: The locus of all points in the binocular field of vision, the images of which fall upon identical points on the two retinas, viz., the images of which are normally seen as single.

Hue: The attribute of color which is typically determined by the dominant wave-length or predominant wave-lengths of the stimulus, and commonly referred to as red or yellow or green or blue or some intermediate.

Identical Points: Any pair of retinal points in the two eyes which, when the eyes are in the primary position, receive stimuli from the same objective point at infinite distance.

Idioretinal Light: Visual impressions of light which occur in the absence of adequate light stimulation, and are attributed to physiological processes within the retina itself or in the brain.

***Illuminance:** The density of light-flux incident upon a surface. Common units of illuminance are the footcandle, meter-candle, and the lux or lumen per square meter.

Illuminant Color: Color seen as glowing, luminous, or belonging to an illuminant, viz., in the illuminant mode of appearance. Commonly referred to a comparatively small area of high brightness, viz., brighter than white under similar conditions of viewing. Examples: color of perceived flame, tungsten lamp, neon sign, fluorescent fabric. Also called glow, glowing color.

Illumination Color: Color seen as belonging to illumination distributed in space, viz., color in the illumination mode of appearance. Examples: color of sunlight in a room, red light flooding a stage, etc.

Illumination Flicker: Flicker seen as belonging to the illumination of the illuminated space rather than to the surfaces or objects seen in it.

***Illumination, Law of:** The principle that the illuminance of a surface varies directly as the luminous intensity of the light-source, inversely as the square of its distance, and directly as the cosine of the angle made by the light-rays with the perpendicular to the surface.

***Image, Optical:** The picture or reproduction of an object produced by a lens, reflector, or optical system, as a result of the focusing in the light emanating from each point in the object.

Image, Retinal: The optical image of external objects formed upon the retina by the refracting surfaces of the eye.

Induced Color: A color or change in color which appears in a given portion of the subjective visual field, due not to direct stimulation of the corresponding portion of the retina, but to concomitant stimulation of other portions.

Inducing Color: A color-stimulus which induces a contrast effect. Distinguished from induced color, the color that constitutes the effect.

Insistence: Power of catching the eye or forcefulness of colors; associated with brightness of achromatic colors and saturation of chromatic colors.

Invariable Hues: The invariable hues are those which are independent of the Bezold-Brücke phenomenon, i.e., those hues which do not change with change in luminance of the stimulus. Purdy's average values for the spectrum stimuli to the invariables are: 474, 506, and 571 millimicrons, respectively.

Irradiation: The apparent excess in size of a visual stimulus of relatively high intensity, e.g., of a white stimulus figure on a black ground, as compared with an equal black stimulus figure on white.

Just Noticeable Difference: The least difference in value between two compared stimuli which, in a given individual, gives rise to two different sensations. Abbreviated j.n.d. Also called just perceptible difference, least noticeable difference, minimal change.

Ladd-Franklin Theory of Color Vision: A theory which assumes that in the retinal nerve-endings the respective light-stimuli liberate red-, green-, and blue-stimulation substances from a complex photosensitive molecule, and that, of these, red and green, when present, unit to form a yellow-stimulating substance, which may in turn unite with blue to form a white-stimulating substance. According to this schema blue and green, or blue and red, cannot so unite, and so do not individually disappear in the respective blue-green and blue-red (or purple) mixtures; dichromatic vision is explained by the assumption of a less highly developed molecule, and for the achromatic or colorless vision of the rods the original molecule is still more primitive.

***Lambert:** Unit of luminance equal to 1/pi candles per square centimeter, or to the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square centimeter, or to the average luminance of any surface emitting or reflecting light at the rate of one lumen per square centimeter.

Light (adj.): Characterized by a relatively high degree of lightness.

Light (n): Radiant energy of those wave-lengths which act as adequate stimuli to the visual sense.

Light-Adapted Eye: An eye which has been exposed to light stimuli of relatively high intensity and has so become relatively insensitive to lower intensities. Cf. adaptation.

Lightness: That attribute of most object colors by reference to which they can be classed as equivalent to members of the achromatic series ranging from black to white.

Light Sensation: A kind of sensation whose adequate stimulus is light and whose receptor is the eye.

Light Waves: Luminous radiant energy, when regarded as an undulatory or wave-like phenomenon; or as a transverse electromagnetic disturbance.

Limen: Same as threshold.

Located Color: A color in a mode of appearance which makes the stimulus object appear to be within definite limits of distance from the observer.

***Lumen:** The unit of luminous flux. It is equal to the flux through a unit solid angle (steradian) from a uniform point source of one candle, or to the flux on a unit surface all points of which are at unit distance from a uniform point source of one candle

***Luminance:** Luminous flux emitted, reflected, or transmitted per unit solid angle and unit projected area of the source. Usual units are the candle per square meter, the candle per square foot, the lambert, the millilambert, and the foot-lambert. This quantity has commonly been called photometric brightness in the past.

***Luminosity:** A measure of the visibility or brightness-producing capacity of

radiant energy consisting in the ratio of photometric quantity to corresponding radiometric quantity in standard units (lumens per watt).

***Luminosity Coefficients:** The coefficients by which the color mixture data for any color need to be multiplied so that the sum of the three products is the luminance of the color sample to be specified.

***Luminosity Curve:** Curve of photopic luminosity of spectrum stimuli through the visible range, plotted as a function of wave-length with maximum luminosity as unity. There is also a scotopic luminosity curve.

Luminous: Characteristic of the illuminant mode of appearance, glowing, viz., having the appearance of emitting light.

***Luminous Flux:** Rate of transfer of luminous energy. The usual unit is the lumen.

***Luminous Intensity:** Flux emitted per unit solid angle about a source. The usual unit is the candle.

Luster: A high-light or glossiness perception in which shifty bright areas are seen upon the surface of an object. Luster is characteristically experienced when observing a somewhat irregular and more or less polished metal object.

***Lux (Meter-Candle):** Illuminance of a surface one square meter in area receiving uniformly distributed flux of one lumen, or the illuminance produced at the surface of a sphere having a radius of one meter by a uniform point source of one international candle situated at its center.

Macula, Macula Lutea: A yellow pigmented area of irregular shape and variable from one individual to another, situated centrally about the fovea of the retina. Also called yellow spot.

Magenta: 1. The hue attribute of visual sensations typically evoked by stimulation of the normal human eye with a wave-length combination which is the approximate complement of 515 millimicrons. 2. Any hue predominantly similar to that of the typical magenta. The complement of green.

Marginal Contrast: An accentuated type of simultaneous contrast, which occurs in regions close to the boundary between two contrasting areas.

Maxwell Disk: Two or more radially slit and concentric color disks overlapping by adjustable amounts, and rotated above the flicker threshold to yield a color mixture by the method of rapid alternation.

Median Gray: An intermediate gray which is characterized as neither whitish nor blackish.

Memory Color: Color as remembered, of an object, film, or illumination. The memory colors of an individual exert more or less influence in the determination of the colors of the familiar objects which he perceives.

Mesopic Vision: Vision intermediate between photopic and scotopic vision, and consequently attributed to the combined functioning of the rods and cones.

Metallic Color: Color typically evoked by selective reflection from certain metallic and other surfaces which possess the physical feature known as metallic reflection, and which exhibit chromatic high-lights similar in hue to the surfaces as a whole.

Metamerism, Metameric: Terms referring to the characteristic property of

metamers, and often used to express degree of the phenomenon, as slightly metameric, extreme metamerism, etc.

Metamers, Metameric Colors: Color stimuli which have different spectrophotometric characteristics but which elicit identical colors under favorable conditions of comparison.

Micro-Structure: The texture or grain of the surface of an object, which often affords effective clues to the recognition of the object.

Mirrored Color: Color seen as in a mirror behind the reflecting surface.

Mode of Appearance: A perceived aspect or condition of the appearance of a color, which tends to have a spatial and sometimes a temporal character. The commonly recognized modes of appearance are: film, surface, volume, illuminant, and illumination.

Mode of Appearance, Attribute of: One of the various characteristic features of a mode of appearance, some of which are invariably present and some, not. An example of an attribute of a film is softness, of a surface is glossiness, of a volume is transparency, etc.

***Monochromatic Vision:** Also called monochromatism.

***Monochromatism:** Form of vision in which the colors can be matched with a single adjustable primary.

***Monochromator:** Spectroscope in which the ocular lens is replaced by a slit to isolate a narrow portion of the spectrum.

Munsell Book Notation: Munsell color notation as applied to the hue, value, and chroma scales of the 1929 Munsell Book of Color (to be contrasted with Munsell renotation).

Munsell Color Notation: A system of letters and numbers by which the Munsell color samples are "notated" or specified with respect to hue, value, and chroma. Unspecified surface colors can be specified by comparison with the Munsell samples and assignment of the appropriate notation.

Munsell Colors: A series of about 1000 standard samples of chromatic and achromatic surfaces, each specified by a letter-number system of notation with respect to Munsell hue, value, and chroma (analogues of hue, lightness, and saturation).

Munsell Renotation: Munsell color notation applied to the hue, value, and chroma scales in accordance with the recommendations of the OSA Subcommittee of the Colorimetry Committee on the Spacing of the Munsell Colors.

***Nodal Point:** The point in the eye through which all straight lines pass which join points in the stimulus field with their respective retinal images.

***Normal (Optics):** The perpendicular to a surface at the point where a ray of light is incident upon, reflected or refracted from, the surface.

Object Color: Color seen as belonging to an object. This includes surface and volume colors to the extent that surfaces and volumes are perceived as objects or parts of objects. Object colors are relatively insensitive to changes in viewing conditions, viz., they exhibit the phenomenon of constancy.

Ostwald Colors: A series of several hundred chromatic and achromatic samples, each corresponding to a certain theoretical pigment combination of "full color content, white content, and black content"; and designated in an arbitrary letter-number system of notation.

Paracentral Vision: Vision mediated by the zone of the retina immediately surrounding the *fovea centralis.*

Perception: Recognitive awareness or identification of external objects, spaces, motions, times, relations, etc.

Perimeter: An instrument for mapping the sensibility of the retinal field; it consists typically of a quadrant rotating about one of its limiting radii as an axis so that on every point of this arm, and at every angle (corresponding to some point on the retina) a stimulus can be given and the visual impression recorded on a chart, the eye being placed at the center of the quadrant and fixated upon its center of rotation. Sometimes a semi-circular arm is used rotating about its middle radius. Cf. Campimeter—for mapping the retinal field on a flat surface.

Perimetry: The operation of mapping the sensibility of the retinal field by reference to visual responses to controlled stimuli, as with a perimeter. The similar operation of campimetry yields a systematically distorted map because in the campimeter the map is projected upon a flat rather than a spherical surface.

Periphery of Retina: The region of the retina remote from the center of vision, as distinguished from the central region.

Phenomenal Regression: The principle that the percept is of an intermediate nature between the expectation of the constancy hypothesis and the objective reality, viz., that the percept is a regression from the one toward the other. Cf. Constancy.

Phosphene: A bright form in the dark field of vision, produced by distortion of the eyeball either during the normal process of accommodation and convergence or by pressure from an external object.

Photochromatic Interval: The range of visual stimulus-intensity, for a chromatic stimulus, between the absolute threshold or limen for light-perception, and the threshold for hue. There is said to be no photochromatic interval for long-wave light, i.e., in the red end of the spectrum. Also called colorless interval.

***Photometer:** Any optical device which utilizes equations of brightness to permit the measurement of candlepower, illuminance, or luminance. The equality-of-brightness photometer employs simultaneous comparison of juxtaposed visual areas; in the flicker photometer the stimuli which are to be compared are presented successively in the same visual area.

***Photometric Measure:** A measure of luminous radiant energy in photometric terms, rather than in terms of sensation-magnitude, on the one hand, or of physical energy on the other.

***Photometry, Visual:** The measurement of luminous radiation on the basis of its effect upon the visual receptors; under standard conditions, and usually involving an adjustment of two contiguous parts of the visual field, either to identity or to a minimal difference. Heterochromatic photometry involves the measurement of the relative intensity of differently colored radiations. Cf. Flicker Photometry.

†**Photon:** A unit of visual stimulation defined as that illumination upon the retina which results when a surface brightness of one candle per square meter is seen through a pupil of one square millimeter area.

Photopic Adaptation: The decreased visual sensitivity to light, sometimes manifest by decreased brightness of a fixed stimulus, which is dependent on relatively intense light stimulation.

Photopic Vision: Vision as it occurs under illumination sufficient to permit the full discrimination of colors. Believed to depend upon the functioning of the retinal cones instead of the rods alone. Also called daylight-vision. Contrast with twilight or scotopic vision.

Photoreceptive (or **Photoreceptor**) **Process:** That specific process which is set in motion in a visual sensory end-organ or other photic receptor by the incidence of its adequate simulus, i.e., light. It is usually assumed to be a photochemical change of some sort, e.g., the decomposition by light of visual purple of the retinal rods.

Photoreceptor: The visual receptor, the adequate stimulus for which is the luminous energy of the spectrum.

***Primary Colors:** Three colors whose normal stimuli, when mixed additively in proper proportions, are capable of yielding colors of all hues (within a wide range of saturations) and the gray series. This usage relates especially to theories of color vision of the tri-receptor type.

Primary Hues: The four psychologically simple or unique hues of normal trichromats. A primary hue is unmixed, viz., it does not partake of the specific nature of any one of the other three; thus a primary red is neither bluish nor yellowish nor greenish, the primary yellow is neither reddish nor greenish nor bluish, etc. Also called psychological primaries, principal hues, unitary hues.

Primary Position: The position which the eyes assume when the head and body are erect and the eyes fixate an infinitely distant point in the median and horizontal planes.

Pronouncedness: That property of surface or object colors, related to the lightness of achromatic colors and to the characteristic or "proper" hue of chromatic colors, whereby their quality is accentuated or holds up under adverse conditions, e.g., under low illuminance.

***Protanomaly:** Form of trichromatism in which the luminosity curve is abnormally low at the long-wave end, and an abnormally large proportion of stimulus red is required in a red-green stimulus mixture in order to match a given yellow.

***Protanope:** Individual having protanopic vision.

***Protanopia:** Form of dichromatism in which red and blue-green stimuli are confused and the luminosity is abnormally low at the long-wave end; but a normal proportion of red and green stimuli suffices to match a given yellow. Sometimes called red blindness.

***Pseudo-Isochromatic Charts:** Charts for testing color deficiency, comprised of colored spots which yield a recognizable pattern (number, letter, irregular line) to a normal observer, but yield a different or not recognizable pattern to an abnormal observer.

Psychic Blindness: Inability to see due to some impairment of the cerebral cortex, the receptor being normal. Properly limited to psychogenic (hysterical) inability to see. Distinguish from mind blindness—a condition in which one can see, but cannot understand or interpret (apperceive) what is seen.

Psychological Primaries: Same as primary hues.

Pure Color: Any color stimulus which, like the spectrum colors, approaches the condition required for maximum saturation.

Purity: A measure of the degree to which a color stimulus approaches the condition required for maximum saturation. There are various measures of purity, but all of them are based on the ratio of the spectrum and achromatic components of the stimulus mixture.

Purkinje After-Image: The second positive visual after-sensation which appears most plainly in the hue complementary to that of the primary sensation.

Purkinje Phenomenon: A phenomenon concerning the perceived brightness of different color stimuli, namely, that as the spectrum is darkened, the long-wave end darkens more rapidly than the short-wave end, e.g., red brightens in an intense general illumination, blue in faint illumination. Concomitant dark adaptation is required, since the effect rests upon the transition from cone to rod vision.

Purples: A series of related hues, ranging between blue and red, and normally evoked by combinations or mixtures of long- and short-wave radiation within the visible spectrum.

***Radiant Energy:** Quanta of energy travelling through space in the form of electromagnetic waves of various lengths.

***Rayleigh Equation:** Proportions of red and green stimuli required in a mixture to match a given yellow. Usually a spectrum red (670 mμ) is mixed with a spectrum green (535 mμ) to match a spectrum yellow (589 mμ). The Rayleigh equation is used to differentiate normal, protanomalous, and deuteranomalous trichromats.

Recurrent Image: A visual, auditory, or other image which persistently returns.

Recurrent Vision: A succession of positive and negative after-images or after-sensations. Cf. After-Image.

Red: 1. The hue attribute of visual sensations typically evoked by stimulation of the normal human eye with any combination of long- and short-wave radiation which is visually equivalent to 494c millimicrons. Long-wave radiation, from around 650 millimicrons to the end of the visible spectrum, normally evokes a series of reds which are scarcely distinguishable from the typical, extraspectrum red. 2. Any hue predominantly similar to that of the typical red. The complement of blue-green or cyan.

***Red-Green Blindness:** A common form of partial color blindness, or dichromatism, in which red and green stimuli are confused because they are seen as various saturations and brightnesses of yellow, blue, or gray. Cf. Protanopia and Deuteranopia.

***Red-Sighted:** Displaying a heightened color sensitivity for red, or a tendency to see all objects tinged with red; due to (a) some unknown variation in the eye or nervous system, or (b) following prolonged exposure to the stimulus for the complementary green, or (c) sequent upon over-exposure to intensive light and possible hemorrhagic. [(c) is also called erythropsia.]

Reduced Color: Color seen as filling a small aperture in a (usually neutral) screen.

***Reduced Eye:** A simplified schematic system designed to have the same optical properties as the average unaccommodated human eye.

Reflected Color: Color seen as reflected from a perceived object.

Retina: The innermost of the three coats of the eye ball, which receives the image formed by refraction at the cornea and lens, and serves as receptor organ for vision. In the human retina 10 layers are distinguishable, of which the layer of rods and cones, the second from the exterior, is the specific visual receptor.

Retinal Field: The extended mosaic of the rod and cone receptor elements of the retina, which forms something of an anatomical correlate of the stimulus field.

Retinal Illuminance: The illuminance of the retina, the usual units being the troland and the lux.

Retinal Oscillations: A variation in the state of excitation of the visual neural apparatus following a single momentary stimulation, which is experienced as a brief succession of alternating bright and dark phases, such as Charpentier's bands or recurrent after-images.

Retinal Rivalry: Alternation of sensations first from one eye and then from the other, when the two eyes are simultaneously stimulated by different colors or figures. Also called binocular rivalry. Contrast with binocular fusion, in which the two impressions are fused into a single impression.

Retinal Zones: Same as color zones.

***Retinitis Pigmentosa:** A pathological condition of the pigmentary layers of the retina, accompanied by diminished color sensitivity (especially for blue), retracted color fields, and lowered power of dark adaptation.

Ridgway Colors: An early system of 1115 pigment colors, chosen to represent by relatively equal steps, a wide range of variation in hue, saturation, and lightness. Designed originally for naming the plumage colors of birds.

Rod, Retinal: A rod-shaped structure found in the retina of the eye which constitutes a specific receptor for vision. The rods in the human eye are 0.04 to 0.06 mm. long and about 0.002 mm. in diameter. Distinguish from retinal cones, another visual receptor; the rods contain visual purple and are believed to operate for achromatic (gray) visual qualities at low (twilight) stimulation-intensities, the cones for chromatic and achromatic at the higher levels of stimulation; the rods and cones form the second layer of the retina from the outside, lying just within the layer of pigmented cells; it is estimated that there are about 130,000 rods in the human retina; at the center of the retina there are no rods, farther out they are more numerous than the cones.

Rod Vision: Sight or vision in which only the rods function; the cones of the retina do not participate. Also called twilight vision, scotopic vision.

Saturation: The degree to which any color possessing a hue differs from a gray of the same brightness.

Saturation Scale: A graduated series of color stimuli which under appropriately controlled conditions of observation, are perceived to vary by uniform steps in saturation alone.

Scotoptic Adaptation: Like dark adaptation, but more explicit reference to the part played by the rod-system of the retina.

Scotopic Vision, Scotopia: Vision which occurs in faint light, or in dark adaptation. It is attributed to the operation of the retinal rods.

Sensation: Primitive awareness, or uninterpreted conscious response to stimulation of a sense receptor.

Shade: Any color darker, i.e., of lower lightness, than median gray.

Sight: Same as vision.

Snow-Blindness: A temporary abnormality of the color sense, in which all objects are tinged with red. Caused by long-continued exposure to very bright light, as in Arctic exploration, on glaciers, in telescopic observation of the sun, watching welding operations, etc. Cf. Erythropsia.

Sparkle, Glitter: Changes of limited extent in color, especially in brightness, and involving movement.

***Spectrometer:** A spectroscope fitted with a divided circle or wave-length drum for isolating or identifying wave-lengths or regions of the spectrum.

***Spectrophotometer:** A combination monochromator and photometer used to measure spectral emittances, transmittances, or reflectances.

***Spectroscope:** An instrument for making a spectrum visible. The usual prism spectroscope consists of a slit, collimator, prism, and a second lens.

***Spectrum:** A band of radiant energy in which, after passing through a prism or being otherwise dispersed, energy of each wave-length is segregated and all components lie spread out in regular order.

Spectrum Colors: The series of saturated colors normally evoked by photopic stimulation of the retina with radiant energy of continuously differing single wave-lengths through the visible range. Purple is not a spectrum color.

***Spectrum Line:** Any one of the narrow lines, each representing light of a definite wave-length, which are observed in the solar and other spectra, certain groups of lines being characteristic of specific chemical elements. These lines are characteristic of substances in the gaseous state, and appear bright when due to emission from these, or dark when due to absorption by them.

***Standard Observer:** An hypothetical observer with a visual response mechanism possessing the colorimetric properties defined by the 1931 ICI tables of the distribution coefficients, $\bar{x}$, $\bar{y}$, $\bar{z}$, and the trichromatic coefficients, x, y, z, of the equal energy spectrum. The $\bar{y}$ coefficients of the equal energy spectrum are the relative luminosity values defining the standard observer for photometry.

Stimulus Field: The extended totality of visual stimuli which act upon the unmoving eye at a given moment.

Strong Color: A color of high saturation.

Surface Color: Color seen as belonging to a surface, compact in texture, resistant to the gaze and well-localized, viz., a color in the surface mode of appearance. Examples: color of a wall, book-cover, table-top, etc.

Synesthesia: A persisting condition of the individual in which stimulation of one sensory receptor results in experience characteristic of another sensory mode. These experiences may involve any combination of sensory receptors; colored hearing (synopsis) is common but the reverse, tonal vision, is rare.

***Tetartanopia:** Form of dichromatism in which blue and yellow stimuli are confused. The existence of this form is disputed.

Three-Component Theory: See Trireceptor Theory.

Threshold: A statistically determined point or region of the stimulus scale, at which occurs a transition in a series of sensory judgments regarding perceptibility or difference of stimuli. Also called limen.

Tint: Any color lighter, i.e., of higher lightness, than median gray. May imply weak saturation as well as relatively high lightness.

Transformation: The subjective process or mechanism which presumably underlies and accounts for the phenomenon of color constancy.

Transparent Surface Color: A color seen in a two-dimensional mode and possessing among other properties the property of transparency which permits other objects to be seen beyond or behind it. Example: color of a clear glass pane perceived as a transparent plane.

Trichromatic Theory: A color theory based upon the facts of trichromatic mixture, namely that all hues may be derived from the mixture of two or more of three primaries.

***Trichromatic Vision:** Same as trichromatism.

***Trichromatism:** Form of vision yielding colors which require in general three independently adjustable primaries (such as red, green, and blue) for their duplication by stimulus mixture. Trichromatism may be either anomalous trichromatism or normal color vision.

Trireceptor Theory: A type of theory, such as that of Young and Helmholtz, which assumes that color vision depends upon the operation of three kinds of retinal receptors; each of these with its nerve connections comprising a fundamental response process and mediating a fixed fundamental hue quality, all gradations of color being dependent upon the proportions of activity of the three.

***Tritanomaly:** Rare type of trichromatism in which an abnormally large proportion of blue stimulus is required in a blue-green mixture to match a given cyan.

***Tritanope:** Individual with tritanopic vision.

***Tritanopia:** Form of dichromatism in which reddish blue and greenish yellow stimuli are confused. Tritanopia is a common result of retinal disease, but in rare cases may be inherited. Sometimes called blue blindness.

Troland: A unit of visual stimulation defined as that illuminance of the retina which results when a surface luminance of one candle per square meter is incident through an apparent pupil of one square millimeter area. The name of this unit has been changed from photon to troland to avoid the confusion caused by the subsequent physical use of photon as a name for the quantum of electromagnetic radiation.

***Ultra-Violet:** Radiant energy of wave-lengths shorter than the extreme violet and lying beyond the ordinarily visible spectrum. Usually assigned to vibrations below 400 or 390 millimicrons.

Valence, Chromatic: See chromatic valence.

Value: The dimension of the Munsell system of color which corresponds most closely to lightness.

Viewing Conditions: Various conditions under which a visual observation is made, including the size of the stimulus, characteristics of the surround,

nature of the illuminant, area of the retina, etc. Also called conditions of viewing.

Violet: The hue attribute of visual sensations typically evoked by stimulation of the normal human eye with short-wave radiation around 433 millimicrons and shorter.

Visibility: The capacity of radiant energy, within a certain range of wavelengths, to excite a visual receptor process and thereby evoke the phenomenon of brightness.

Visible: Capable of being seen, or represented in consciousness by the operation of the organs of vision.

Vision: The sense whose receptive organ is the eye, whose normal stimulus is radiant energy, and whose response is color.

Vision, Central: Same as vision, foveal.

Vision, Foveal: Visual sensations or perceptions due to stimulation of the *fovea centralis*, or center of the retina. Contrast with peripheral vision.

Vision, Indirect: Same as vision, peripheral.

Vision, Peripheral: Visual sensations or perceptions due to stimulation of the outlying portions of the retina. Contrast with foveal vision.

Vision, Persistence of: The tendency of visual excitation to outlast the stimulus, or more generally the tendency of changes in visual sensory response to lag behind changes in the stimulus.

Visual Acuity: The capacity of the visual organ to resolve small space-intervals in the discrimination of form. The threshold separation of two points or small spots is an inverse measure of acuity but many types of test objects are possible.

Visual Adaptation: Adjustive change in visual sensitivity due to continued visual stimulation. Three recognized types are: (1) scotopic or dark adaptation, (2) photopic or light adaptation, and (3) chromatic or color adaptation.

Visual Angle: The angle subtended by any object of vision at the nodal point of the eye. The magnitude of this angle determines the size of the corresponding retinal image, independently of the size or of the distance of the object alone. The nodal point is about 7 mm. behind the corneal surface and about 17 mm in front of the retina.

Visual Field: The visually perceived three-dimensional space-manifold which is developed from early localizing experiences of the individual and depends for its phenomenal presence at any given time, upon extended areal stimulation of the retina. The visual field forms a subjective frame of reference for perceived objects, distances, movements, etc. Also called subjective visual field, phenomenal field.

Visual Induction: The effect of stimulation from one part of the visual field upon the perceptual response referred to another part. Cf. Brightness Contrast, Chromatic Contrast.

Visual Process: Any change or operation which occurs in vision, or (in certain contexts) the operation of vision in general.

Visual Space: This term, like visual field, refers to the extended world as perceived by means of the eyes; but is commonly used in a more generic and

abstract way in discussions of the perception of distance and length, of depth or distance away from the retina, and of form or figure in two and three dimensions.

Volume Color: Color seen as organized, transparent and filling a tri-dimensional space, viz., color in the volume or bulky mode of appearance. Examples: block of clear ice, jar of jelly, room full of smoke.

***Wave-Length:** The distance, at any instant, between two adjacent crests (or identical phases) of a series of waves which are advancing through a uniform medium. The wave-length varies inversely with the vibration rate, or number of waves passing any given point per unit period of time.

Weak Color: A color of low saturation.

Weber's Law: The difference limen, or the just noticeable increment of a stimulus, is proportional to the stimulus intensity. In vision, the law is approximately verified over a wide range of luminances but fails markedly at low luminances.

White: An achromatic color of maximum lightness which represents one limit of the series of grays, and which is the complement or antagonist of black, the other extreme of the gray series. White is typically evoked by any mixture of wave-lengths from a high-reflectance matt surface, which approximates average daylight or the equivalent color temperature; but white depends also upon surrounding contrast.

Yellow: 1. The hue attribute of visual sensations typically evoked by stimulation of the normal human eye with radiation of wave-length approximately 582 millimicrons. 2. Any color manifesting a hue predominantly similar to that of the typical yellow. The complement of blue.

Yellow-Sighted: Characterizing a heightened color sensitivity for yellow, or a tendency to see all objects tinged with yellow. The phenomenon occurs (1) in individuals who possess a peculiar pigmentation of certain tissues of the eye; (2) in normal individuals following blue-adaptation, or (3) following the use of certain drugs.

Young-Helmholtz Theory: A theory which seeks to explain the phenomena of color vision on the assumption of three independent component mechanisms (or processes) in the retina or its attached nervous apparatus, these mechanisms, when separately aroused (chiefly by radiant energy of corresponding regions in the spectrum) giving rise to the colors red, green, and blue, respectively, all other colors, including yellow, purple, and white or gray being due to various combinations of the three component activities.

TECHNIQUES IN OLFACTOMETRY: A CRITICAL REVIEW OF THE LAST ONE HUNDRED YEARS

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Knowledge of the workings of the olfactory receptor system has not increased significantly in the last fifty years until very recently with the proposed theory of Beck and Miles (**1, 9**). Such a lack of progress is especially striking when contrasted with the great number and complexity of the problems which have been solved in regard to the operation of the other distance receptors. The low scientific production in this area can be traced to two major difficulties. First, there has been a lack of understanding of the dimensions of either the stimulus or the sensation; second, there has been a lack of satisfactory techniques for stimulation. Both needs are equally urgent and satisfaction of either depends, partially at least, upon satisfaction of the other. Their satisfaction requires, also, cooperation from the chemist and the physicist, since it is becoming more and more apparent that the eventual answers will be found in related aspects of psychology, physics, and chemistry. The second need—design of suitable techniques—is somewhat more fundamental than the first. Obviously, it will be impossible to determine the nature of the stimulus without first having a technique for controlled presentation of that stimulus. As the critical features of the stimulus begin to emerge, the apparatus must be modified to make it possible to control the new features.

The present paper is concerned with this need for techniques. It consists of an historical survey of the principal methods previously described and used, the inadequacies of the various techniques, and a brief description of a new one which is believed to be more satisfactory. The discussion will be quantitatively oriented since it is chiefly requirements for threshold measurements that dictate specifications.

Most of the techniques in use before 1925 were devised by European workers and have been described by von Skramlik (**12**) in the *Handbuch der Physiologie der niederen Sinne* and by Henning (**6**) in *Der Geruch*. Gamble's review (**4**) covers some of them but descriptions of the remainder are not available in English. Part I below is a summary of von Skramlik's and Henning's material. Direct references to the investigators named may be found in the two volumes cited. Henning's discussion includes as well references to various workers who used the techniques developed by others.

I. Early Techniques Involving Measurement of Amount or Concentration of Odorous Material

The first apparatus used in the study of olfaction was devised by Valentin and reported shortly before 1850. His procedure was to seal a measured amount of a particular substance in a small, thin-walled glass tube, put this tube inside a larger, thick-walled tube which was then corked, and break the smaller tube, thereby filling the larger container of known volume with a known quantity of odorous material. These steps could be repeated, diluting the concentration more and more by breaking the larger tube in a still larger one, and so on until S failed to detect any odor.

Several modifications of this procedure followed. Berthelot allowed the stimulus material to diffuse throughout a four litre flask. He then drew off whatever volume he needed and mixed it with a certain quantity of odorless air. Passy's method was very similar to that of Valentin. He mixed one part of an odorous substance with so many parts of ethyl alcohol, then diluted the solution 10, 100, 1000, etc. times. For threshold measurements he evaporated a drop of the least diluted solution in a flask and asked S if an odor was perceptible. If it was, the same procedure was repeated with progressively more dilute solutions until no odor was present. Henning's procedure was to allow a measured quantity of material to evaporate in the first of a series of connected bottles. The vapor spread through the other bottles in the series, forming concentrations which varied as $1:\frac{1}{2}:\frac{1}{4}:\frac{1}{8}$, etc. Smaller concentrations in individual flasks were obtained by placing in the bottom some material which would unite with the stimulus material and weaken its potency.

Henning also devised a "gasvolumetric" technique by which he could measure the amount of gas inhaled. The essential feature of the apparatus was a glass U-tube, one arm of which was calibrated as a burette and could be closed on top by means of a stop-cock, while the other arm was open. The tube was partly filled with mercury and was connected to a mercury reservoir which could be raised and lowered. For test purposes, a certain quantity of odorous gas was put into the burette arm by pushing the mercury to the top, attaching the source of gas above the cock, and lowering the mercury reservoir. The mercury in the tube dropped and some of the gas was drawn into the burette. The cock was then closed and the source removed until stimulation. The number of cubic centimeters of gas within the apparatus could be measured, as well as the amount withdrawn by a sniff. The tube was surrounded by a water bath in an effort to control temperature.

The ingenious Zwaardemaker constructed a "smell cabinet" of

aluminum with inner walls of glass which were removable for easy and efficient deodorizing. The cabinet measured 40×40×40 cm. In the back wall was a hole cut to accommodate the nose and kept closed except during actual stimulation. Some measured quantity of the substance being tested, either in a dish or in filter paper which had been soaked in it, was allowed to evaporate inside the closed cabinet. When evaporation had been completed, S inserted his nose in the hole and sniffed the contents of the cabinet. This was an elaboration of the cruder technique of Fischer and Penzoldt who merely allowed the material to evaporate in a small, hard-walled laboratory room.

The Hofmann and Kohlrausch technique was somewhat more elaborate. Saturated fumes were stored over mercury in one tube and mixed with air in a graduate. The diluted air was blown under low pressure through nosepieces into the nostrils. The gram fraction of odorous substance in 1 cc. of air could be computed, knowing the pressure, volume, and specific gravity of the pure substance. Dibbits' method was specific to the particular substance for which he was measuring the absolute threshold, viz., acetic acid. By passing damp air over a certain amount of dry salt at a temperature of 80°C., a measurable quantity of acetic acid was liberated since the salt cannot take up water at that temperature.

Savelieff connected two flasks by means of glass tubing, placing odorous liquid in one and allowing it to diffuse into the other which had a nosepiece attached. Dilution was accomplished by adding specific quantities of water to the contents of the first flask.

Ónodi prepared different concentrations, then soaked a ball of cotton in any one of them. This ball of cotton was attached to the bottom of the stopper of a bottle which had another opening, also. The odor on the cotton was allowed to diffuse through the bottle, whereupon S sniffed at the second opening.

Grazzi used as the source of odor a strip of filter paper which had been soaked in a substance dissolved in alcohol. This was allowed to dry so that the alcohol odor disappeared. The paper was then hung in a small pasteboard box closed on all sides, except for one hole in the top. The diameter of the hole varied from 0.5 to 5.0 cm. in a series of prepared boxes. A paper funnel 10 cm. high and with a 5 cm. diameter fit over the hole. S sniffed at the open funnel, starting at the box with the smallest hole and continuing until an odor was experienced. The threshold was stated in terms of size of hole.

The methods devised by Sternberg and von Rothe made use of a pump to send the odorous air into S's nostrils. Sternberg prepared a

desired concentration in a flask which had a pump at the neck. The mixture was then blown into the nose. Von Rothe drenched a piece of filter paper in a given concentration of an odorous liquid and hung the paper in a wide glass tube. By means of a pump, air was blown through the paper and into the nostrils.

Determination of the threshold in terms of the distance of S's nose from the odorous source was done by Fröhlich. A flask containing a certain concentration of a substance was left open in a small room. S, in the same room, reported the first sensation he received from each concentration. Results could be stated in terms of the time between opening the flask and S's report as well as the distance of the flask from S. The many possible errors attending the use of the method are obvious—absorption by objects in the room, effect on direction and rate of diffusion of various air currents, changes in concentration following diffusion, effect of room temperature, etc.

A related form of this technique was used by Henry. His olfactometer consisted of two main parts. First, there was a stoppered flask, containing an odorous liquid. The second part was a cylinder inserted through the stopper to a point just above the level of the liquid in the flask. The bottom of the cylinder was covered with a permeable paper membrane. A glass tube led out of the cylinder to a double nosepiece. The air in the cylinder could escape only through the tube to the nosepiece. Molecules of the odorous liquid passed through the paper into the cylinder and thence into the nose when S sniffed at the nosepiece. To measure the threshold, the tube was first placed so that its opening was just above the paper, then gradually raised until S reported a just-noticeable odor. The elevation necessary for a sensation to occur was the threshold.

Most of these procedures had two features in common. First, they were devised to determine absolute limens as these limens depended upon some measure of the absolute amount or the concentration of the stimulus substance; and second, the construction material was glass. There are at least seven sources of error to which they were liable.

1. Probably the least important possibility for error was absorption of the substance by the glass. Still, with an exceedingly small concentration, even such a slight reduction could prove to be very important. In any work with absolute thresholds, the stimuli required are often minute in quantity. This is especially true in olfaction where discrimination for some substances is extremely keen. Accordingly, very weak concentrations were often necessary and calibration could have been rendered inexact by the factor of absorption by the container.

2. More important was the factor of dilution when the bottle was opened for S. Again the greater effect would occur in the case of the smaller concentra-

tions. Sometimes a container was prepared and opened only once; at other times many exposures to individual stimuli were given, allowing for pronounced dilution.

3. A third source of error lay in the assumption that proportional concentrations of the same substance yielded proportional stimulus intensities. This is not true as far as the number of molecules is concerned; e.g., an increase in the concentration from 1/100 to 1/10 does not result in an equivalent increase in the number of molecules.

4. A fourth source of error must be considered where non-volatile substances were used which had to be dissolved in some medium which would then evaporate. The medium selected was often one possessing a distinct odor of its own, such as alcohol or acetone. In such cases the purity of the stimulus would be impaired through corruption by any residual odor of the dissolving substance.

5. In the case of highly volatile substances a different difficulty was present, that of weighing without loss from diffusion before the stimulus could be covered in its container.

6. Fluctuations in temperature may also have affected the nature of the stimulus. Recent researches (5, 15) have shown that a variation of the temperature of the stimulus above or below normal room temperature causes a pronounced change in the apparent intensity of the odor.

7. Finally, there was the ever-present problem of controlling the size of S's inhalation. It would seem that the instructions with this type of apparatus could be the simplest possible; e.g., "Sniff the contents of this bottle and report whether or not you perceive an odor." In the one word, "sniff," can be found the source of the lack of control of the stimulus magnitude. Does "sniff" mean a small inhalation or a large one? Even if the experimenter characterized it as a moderate sniff, he was still at the mercy of his S's interpretations of "moderate." Assuming that all of the other errors could have been eliminated, thereby controlling the stimulus completely as far as the nostrils, lack of control from that point on would shed serious doubt on the comparability of the data from S to S or even from trial to trial for a single S. Obviously, some means of controlling this feature of the stimulus is very necessary. Some of the apparatus described above included a pump to raise the air into the nostrils, eliminating the voluntary and variable inhalation, but probably introducing unwanted odors from the pump mechanism.

II. Zwaardemaker's Olfactometer—Avoidance of Concentration Determinations

The Zwaardemaker olfactometer marked a different approach to the problem of controlled stimulus presentation. The apparatus is a familiar one. The stimulus material is enclosed in a long hollow tube with one sealed end and perforated on the inner surface. This tube slides over a glass tube, open at both ends, which leads through a screen to S's nose. As less and less of the inner tube is covered by the outer tube, more and more of the latter's perforated inner surface is exposed, allowing a greater amount of the odorous substance within it to escape into the glass tube and into S's nose when he sniffs. Zwaardemaker (18, p.

118) suggested the use of a standard olfactory unit—the olfactie. He defined the unit as the normal perceptible minimum odor and stated it in terms of the amount of exposure of the perforated surface in cm. The value was determined separately for many substances by testing several structurally and neurologically normal Ss and selecting the modal exposure length. One olfactie of India rubber was equal to 0.7 cm. Any individual's threshold could then be stated as so many olfacties.

Here was an apparently quantitative and yet simple method at last available. The method was an indirect one, in that the problem of stimulus concentration was avoided. This had not been true in those previous techniques which had used an indirect unit of intensity in stating the threshold, e.g., those of Grazzi and Henry. There was also a double olfactometer, actually a pair of single ones, so that the two nostrils could be stimulated independently. A wide variety of stimulus materials could be used, since the tube was adaptable for either liquids or solids. In experiments involving a number of stimuli, a different tube was constructed for each substance and was slipped into the apparatus when wanted. Gamble described the construction of fillers of solid materials such as vulcanized India rubber, Russian leather, and cocoa-butter. To accommodate fluid stimuli, she used the so-called fluid-mantle olfactometer consisting of a very porous porcelain tube inside of a glass tube. The odorous liquid was injected between these two cylinders by means of a pipette through one of two tiny holes in the metal end-plates. The inhaling-tube projected inside the porcelain cylinder. Examples of stimuli used in this apparatus are citral in liquid paraffin and pyridin in water.[1]

Many of the same criticisms which were applicable to the earlier techniques are also valid in connection with the Zwaardemaker olfactometer. Adhesion to the surface is a more urgent problem if the same inhaling tube is used for many substances. Temperature of the material and size of S's sniff are still left largely uncontrolled. Zwaardemaker (17) himself designed another type of olfactometer to meet this latter difficulty. In a description of his "Präzisionsolfaktometer" he mentioned the advantage of being able to control the "drawing-in" of the air. He accomplished this by inclusion of a pump into a piece of apparatus otherwise similar to his standard olfactometer. The pump forced air at a constant rate through the apparatus. At the same time the smelling tube was moved forward a certain amount, exposing more of the odorous surface. If the concentration was above the stimulus threshold, the

[1] A few additional devices similar to Zwaardemaker's and others mentioned above are described by Moncrieff (10).

intensity could be decreased by reducing the force of the pump. Otherwise the pump was operated at a constant rate. Zwaardemaker noted that the threshold varied directly with the pressure produced by the pump. He recommended the use of this olfactometer for clinical tests of partial and complete anosmia resulting from a variety of causes such as flu and hemiplegia.

An additional source of error is present in the Zwaardemaker device in that some odor may escape from the stimulus tube even when none of the perforated inner surface is exposed. Gamble reported this error for both solids and liquids in her experiment. Use of the olfactie as the unit of measurement is based upon the assumption that zero stimulation occurs at zero exposure and that a progressive increase of exposure causes a proportional increase in the saturation of the air current created by sniffing. Gundlach and Kenway (5) have discussed the inaccuracies of this concept, pointing out that complete saturation of air occurs when a state of equilibrium is reached between the partial pressure of the vapor in the air and the vapor pressure of the volatile substance. Once this has occurred, provided no significant temperature change is introduced, no further saturation is possible.

III. Recent Techniques

The various types of olfactometer which have been developed in the last thirty years have been attempts to correct or avoid errors resident in the earlier devices and, in some cases, to take cognizance of the molecular count. Certain requirements have been set up regarding the apparatus which, if satisfied, would insure reliable results. Elsberg and Levy (3) list the following conditions as necessary for measurement of olfactory thresholds:

1. The test should be extremely sensitive.
2. It should be quantitative so that degrees of alteration of sensitivity can be stated precisely (e.g., 20/20 smell).
3. The distinction between the olfactory and the trigeminal components of any odor should be realized.
4. Some manner of conveying the stimulus to the receptor besides breathing or sniffing should be resorted to.
5. The volume of the stimulus should be controlled and measured.
6. The force, i.e., the pressure, of the stimulus should be controlled and measured.

Gundlach and Kenway specify certain other requirements for quantitative work:

1. The air should be pure and odorless.
2. The humidity and temperature of the experimental room should be controlled.

3. The intensity of the stimulus should be controlled and expressed in some common scientific unit.

4. The construction materials should be odorless throughout and able to be frequently and thoroughly cleaned.

The two lists are complementary rather than contradictory. An additional item might be included, namely, that the nosepiece through which the stimulus is presented to S should be comfortable and especially constructed to fit the nostril. With these points in mind, a brief discussion of recent olfactometers follows.

The first of these was designed by Woodrow and Karpman (16) in an attempt to control directly the physical intensity of the stimuli. Their aim was to express the intensity in terms of the proportion of odorous molecules in the total stimulus. It was achieved by treating the stimuli in accordance with Avogadro's principle, that equal volumes of a gas or gas mixture at the same pressure and temperature will have an equal number of molecules. Inasmuch as the number of molecules of a gas in a gas mixture is proportional to the partial pressure of the gas, and the partial pressure is in turn equal to the vapor pressure which is in turn equal to the vapor tension of the liquid forming the gas, the number of molecules can be stated indirectly by means of the vapor tension. Since vapor tension varies directly with temperature, all that is necessary for control of the physical intensity is a preliminary determination of the vapor tensions of different liquids at several temperatures and then regulation of the temperature. In their apparatus, pure air was sent through Emmerling absorption tubes where the odorous material was kept at a constant temperature. The air current was then warmed to 33°C., in order to eliminate a temperature differential among the stimuli, and passed into S's nose. In this way continuous stimulation could be given if desired, as in the experiment reported by the authors where adaptation times were being measured. One drawback to the method is its restriction to liquids. For use with such materials, however, it offers a physically accurate and fundamental technique. Nevertheless, it has not been used by any later workers.

A new technique for preparing different concentrations was described by Rennes (11) for use with camphor. The apparatus had four chambers. The first was the distribution chamber where pure air was received from a bellows. Part of this air was sent into an odorless tube (Chamber 3) where it circulated freely. The rest was sent through a tube (Chamber 2) containing first a carbon filter soaked in oil of pure vaseline and then over pulverized camphor. The filter served the purpose of absorbing odor in case any air moved backward into the first

chamber. Finally the two divergent streams of air from chambers 3 and 2 recombined in the fourth chamber. The amount of each which was admitted here was regulated by variable diaphragms covering the two orifices. Control of the concentration was achieved by control of the diaphragms which had been previously calibrated for this purpose. The manner of expressing the concentration was not explained. In the absence of the necessary controls, we can assume that it was not in molecular or molar terms. The air which was still in motion from the impetus given it by the bellows passed into a glass tube and thence into a small funnel. A funnel was considered superior to a nosepiece because it prevented leakage and gave more widespread stimulation.[2]

A high degree of precision was achieved by Gundlach and Kenway in an olfactometer designed to be used for measuring absolute thresholds. The thresholds were stated as molar ratios of odorous material to pure air. They could be converted into molecular counts, if desired, by multiplying by Avogadro's number.

Essentially, the apparatus had three main sections. One was a line of pure air for comparison purposes. The other two produced the odorous stimulus. One of these two was a dilution line, the other an odorous line. All three lines were set in motion by running water into a 20 gal. carboy and hence forcing out the air. The odorous line bubbled through the odorous material. The pressure in this line was then measured on an open manometer and was called the total pressure (TP). It represented the amount by which the pressure in the line exceeded atmospheric pressure. The relative pressure in both the odorous and dilution lines was also measured (PL_3, PL_2). Due to the manner in which the relative pressure manometers were calibrated, these figures really represented the amount of air (in cc.) passing through each line per minute. Stopcocks at the beginning of each line allowed for control over the rates. The two lines were then joined to produce the odorous stimulus. By reference to the relative pressure (or rate of flow) measurements for each line, it was possible to determine the contribution of each to the total. When the vapor pressure of the substance (VP) is known, the mol fraction (VP/TP) can be computed. If this result is multiplied by the ratio of the contribution of the odorous line to the total stimulus $[PL_3/(PL_2+PL_3)]$, the ratio of mols of odorous substance to mols of air is obtained.[3]

[2] Zwaardemaker had used an iris diaphragm on one of his olfactometers—the irisdosimeter—and stated threshold measurements in terms of the size of the opening (12).

[3] It is assumed that the formula given in Gundlach and Kenway's article is in error since it would not give the result stated. The one given above is apparently the correct

The apparatus contained in addition a suitable means for purifying and drying the air and a temperature control. Glass was the principal construction material. For experimentation by standard methods, however, it presents a serious drawback. Rapid adjustments to vary the molar ratio are impossible. Hence, their procedure was to adjust it for a single value and obtain judgments from as many Ss as possible before the carboy was filled with water. On another day judgments were taken for a different setting. In a single session judgments from one S on more than one setting could not be obtained. Such inflexibility of technique is undesirable. Two other criticisms can be made. There is no assurance given that the rate of flow through the odorous substance was always slow enough to ensure complete saturation of the air. If this were not the case, fewer molecules than the computed number would be present. Also, there was no control over the duration of stimulation. Each S sniffed in succession at two dirhinic nosepieces, one set emitting pure air and the other odorous air. The emission was continuous. If one S sniffed a fraction of a second longer than another, he would draw into his nose many more molecules. The absolute number of odorous molecules present is undoubtedly more important than the proportion of those molecules to the non-odorous ones.

In the work of Elsberg and his associates (3) can be found the first adequate control over the actual delivery of the odorous substance into the nostril. The olfactometer was a simple one. Essentially it consisted of a 500 cc. bottle with a syringe and a nosepiece attached. By means of the syringe additional air could be introduced into the stoppered bottle. On the tubing leading to the nosepiece was a pinch-clamp cutting off this exit unless opened by the experimenter. For the purpose of stimulation, a measured quantity of water was put into the bottle with the odorous material which was then allowed to diffuse through the enclosed space. Next, a given amount of air was injected into the bottle while the pinch-clamp was closed, thereby building up pressure so that a blast of odorous air was forced into S's nostrils when the clamp was opened. This blast of air was called the stimulus volume and was equal to the amount just previously injected through the syringe, since this latter quantity constituted an excess over the volume of the bottle and hence was forced out when an exit was available. The force with which it left was determined by both the amount of the excess and the amount of air

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statement. Their formula is:

$$\frac{(VP)(PL_a)}{(TP)(PL_a)(PL_a)}.$$

in the bottle to which it was added. Depending on the water level, there was more or less air in the bottle during a state of equilibrium. A given quantity of air injected into this so-called vapor volume built up a stronger or weaker pressure as the vapor volume was smaller or larger. Conversely, with a given vapor volume the pressure varied directly with the size of the injected volume. The resulting pressures were measured on an open mercury manometer attached at the nosepiece and were stated in terms of millimeters of mercury. The procedure is known as the "blast injection technique." By attaching the bottle to a compressed-air tank as the source of air rather than to the syringe, continuous stimulation was possible. This procedure is called the "stream injection technique."

In one of their experiments Elsberg *et al.* (2) showed that stimulus pressure, i.e., force and impact of the blast on the olfactory cells, rather than volume was the main factor in identification. He continued to state thresholds in volumetric units, however.

Jerome (7) followed up the question of the relative importance of volume and pressure. His experiment consisted of varying each independently of the other in an attempt to discover which was correlated with intensity of sensation. He revised the Elsberg apparatus so that it was possible to change the vapor volume without opening the bottle. A second, larger syringe was connected to a glass tube leading through the stopper to a point just slightly above the bottom of the bottle. By use of this syringe it was a simple matter to add or subtract a given quantity of water. For each water level used, pressure values were determined on a manometer for different excess volumes. Thus, it was possible to vary stimulus pressure and stimulus volume independently. By injecting the same stimulus volume into different vapor volumes, different pressures could be produced; likewise, different stimulus volumes could be injected into different vapor volumes to produce the same pressure. When pressure was varied and volume kept constant, rectilinear functions were the result; when volume was varied and pressure kept constant, the result was straight line functions parallel to the abscissa. Hence, Jerome concludes,

> Our experiments do, however, suggest a correction that was already implicit in Elsberg's work, i.e., that the score . . . should be expressed directly in terms of pressure rather than stimulus volume, since the latter is merely a means of manipulating the former in a constant vapor volume. . . . It has been repeatedly stated that the stimulus effect is independent of stimulus volume in this technique. Such a statement could easily be overgeneralized. The reason that stimulus volume is unimportant is doubtless that even the smallest injected volume in this experiment carried a number of odorous molecules far in excess of those required to excite the necessary number of receptors. Given, then, a

sufficient number of odorous molecules in the stimulus volume, the question becomes how much pressure is required to bring them into contact with the receptors. In this manner pressure becomes the important variable (7, p. 35).

The technique avoids the problem of controlling the physical intensity of the stimulus by making use of a completely saturated source. It is thereby more successful in attacking the crucial question of how much of the stimulus actually comes into contact with the sense organ because the experimenter himself raises the stimulus to the membrane with a force over which he has control. Short of uncovering the membrane and imposing the stimuli directly upon it, the blast injection technique seems to offer the most fruitful possibilities.

There are four main criticisms that are applicable to this general technique. First, it is impossible to determine the number of molecules present in the stimulus. Second, the new air introduced is not purified in any way. Third, odorous materials are used in the construction of the apparatus. The stoppers and tubing connecting the bottle with the nosepiece and syringes were of rubber, albeit pure rubber which is almost completely odorless. The nosepieces were of metal and somewhat difficult to clean because of their construction. The fourth criticism relates to the nature of the "blast." The pinch-clamp was opened by hand, making for very little uniformity in the onset of stimulation from one trial to the next, as well as in duration of the individual stimuli. Due to the precipitous manner of release of the excess volume, the maximum pressure would be obtained at the first instant of stimulation. From then on the pressure would become weaker and weaker and eventually reach zero when atmospheric pressure is again restored to the contents of the bottle. This means, of course, that the stimulus pressure does not remain constant at the measured value throughout the period of stimulation and only a very small proportion of the volume would be delivered at supra-liminal pressure.[4]

Le Magnen (8) has published the most recent description of a "new" olfactometer. He takes exception to the blast injection technique, arguing that it provides stimulation under artificial conditions. He believes that the variation from natural breathing is important enough to

[4] Two other devices have been described briefly in the literature. In the first (14) of these a revolving tray carries a number of stoppered bottles, each having two tubes through which odorous air can be injected into S's nostrils. In the second (13) there is an odorless tube at the bottom of which is a dish supporting one gram of an odorous material. S sniffs at the top of the tube and the dish is gradually elevated until the odor is first perceived. At this point, the amount of elevation is recorded. No effort is made to control either the intensity of the stimulus or the force with which it is delivered. The similarity of this method and the previously described method of Henry should be noted.

make results obtained by this method irrelevant to a study of the normal olfactory process. The importance of the stimulus pressure is recognized but is controlled by attempting to regulate S's speed of inspiration rather than by blowing in the air. A glass cylinder of two litre capacity is filled with dry air from a source maintained at 20°C. The air in the cylinder is kept at atmospheric pressure without being open to the atmosphere by means of a counterbalanced piston at the top. At the bottom of the cylinder is a micro-vaporizer containing odorous material attached to a syringe. When the syringe is pushed in a certain amount a quantity of the stimulus substance is released inside the cylinder and mixes with the air. The mixture is then described in terms of concentration of odorous material. S breathes in the mixture through a nasal mask. The current of air which he inspires passes through a whistle. The tone produced by the whistle varies in pitch according to the speed of inspiration. S regulates his speed to achieve so-called optimal sensitivity by producing a certain pitch from the whistle. In case he finds it difficult to do this, it is suggested that the tone from the whistle be led to one ear while the other ear is stimulated by a tone presented by E. Then S has merely to match the tone from the whistle to the tone supplied him by E.

In view of the incomplete description of the instrument which the author supplies it is unfair to criticize it. It is certainly impossible to evaluate it. It seems safe to say, however, that the significant innovation—control over speed of inspiration—raises a problem just as real as the one it purports to solve. Breathing in such a way as to produce a certain tone cannot be construed as exactly a natural condition. In order to act as an S, one would be required to have a DL for pitch small enough to insure ability to keep variations in inspiration speed within a satisfactory range! There is no clear description of the method of calibration of the syringe-vaporizer unit, nor is there any mention of how S achieves expiration.

IV. A New Procedure

None of the techniques described above has satisfied all of the requirements for an olfactometric instrument. These requirements can be summarized as follows:

1. Obvious precautions such as use of clean and odorless parts and care in handling the odorous substance.
2. Control over the chemical intensity of the stimulus.
3. Control over the physical intensity.

The first of these requirements is met by most techniques. The second is met by those which make it possible to calculate some expression of the

number of molecules present in each stimulus, such as those of Gundlach and Kenway and of Woodrow and Karpman. The third requirement is met by techniques eliminating the variable sniff and substituting a stimulus of known force, such as the procedures of Elsberg and of Jerome. There has been no technique, however, which incorporates both of these last two essential features. Apparently a somewhat new approach was indicated. A description of the author's technique follows. It was designed to eliminate undesirable aspects of previous work and to include all necessary and desirable features.

The two most significant characteristics are the control of the pressure and duration of the stimulus, and control of the number of molecules of the odorous substance in each stimulus. The course of the air through the apparatus will be traced, with an explanation of each step.

Air from the room is pumped into a compressed-air tank of 9 gal. capacity at any pressure up to 20 lb. A diaphragm compressor is used, eliminating contact of the air with oiled surfaces. This tank now serves as a source of supply of air and the pump can be turned off. From here, a small quantity of air is led through an activated carbon filter to remove organic impurities, bubbled through a gas washing bottle containing the stimulus material, and into a second tank exactly like the first. The two tanks are connected by glass tubing of uniform internal diameter. There are two hand-operated shut-off valves, one on each side of the filter. The entire second tank is immersed in a constant temperature bath during experimentation and also contains a quantity of the odorous material under investigation. There is an air-tight, pressure-proof cap in one side of this tank which is removed to allow the material to be inserted or withdrawn. Here the vapor reaches equilibrium according to the regulated temperature.

At the outlet end there is a glass T, one arm of which leads to a magnetic valve just in front of the nosepiece, while the other arm leads to an open manometer. The device controlling the pressure is connected with the interior of the second tank through the top of the latter. The pressure-control unit is patterned after an ordinary gas dispensing tank or a wet spirometer. There is a receiving cylinder half-full of distilled water with the glass tubing from the diffusion tank entering through a water-tight joint at the bottom and extending above the surface of the water. A slightly smaller cylinder fits into the lower one. Since the top of the upper cylinder is closed and the bottom edge is below the water level, it is an air-tight system directly connected with the diffusion tank. Actually, it serves as an extension of that tank. The pressure built up within this system is directly proportional to the weight of the upper

cylinder which is compressing the air within. A series of weights provides various pressures. Since the manometer is always attached, immediate empirical checks on the pressure can be made at any time. The manometer fluid is red gauge oil, lighter than water so that large, easily read excursions accompany small variations in pressure. The conversion into customary mercury units is very simple.

A stimulus is delivered to S by opening the valve between the diffusion system and the nosepiece. This valve is kept thoroughly clean to render it odorless and is greased with a fine grade of pure, odorless vaseline. It is electrically controlled by an automatic timing device. The interval between stimulations and the duration of each stimulation can be adjusted independently to any desired length. The nosepiece is tilted upward at a 45° angle for easy insertion and direction of the stream of air toward the olfactory membrane. Its shape can be described as an elongated oval, designed to fit almost any nostril tightly. The bulb is solid glass built around the same tubing used in the rest of the apparatus. Monorhinic stimulation is used (although dirhinic is possible) and the other nostril is kept closed. S breathes through his mouth. The valve and nosepiece are in a different room from all of the rest of the equipment including the electrical controls. A warning light appears in front of S a few seconds before the stimulus. Both E and S are provided with telegraph keys and lights in circuit for necessary signalling. The tubing connections throughout the system have been reduced to a minimal length to facilitate cleaning.

The technique has been described for use with liquids although it can be adapted for solids. The major change would be the elimination of the washing bottle and the inclusion of an air-agitating unit inside the second tank. With the solid placed in this tank relatively rapid diffusion could be effected.

By use of this technique the force impelling the odorous blast is known and is kept constant throughout the duration of the stimulus by means of the spirometer device described above. The volume of each stimulus is known, also. Due to the control of temperature and the use of substances with known vapor pressures, a calculation of the number of molecules in each stimulus is possible. Thus, it is believed that most, if not all, of the drawbacks described in connection with previous olfactometric instruments have been overcome in this one. Experimentation is in progress to measure the DL for phenyl ethyl alcohol and also to determine the possible effects of fluctuating pressures (the "feel" of the air) on judgments of amount of odor. The results of this research will be reported at a later date.

Summary

The preceding review has described the various techniques which have been in use in olfactometric experimentation, i.e., threshold measurement, since such work formally began 100 years ago. Knowledge of these techniques and their inadequacies is considered especially necessary in olfaction where relatively little is understood concerning the functioning of the receptor. By achieving greater control over the important aspects of the stimuli, the sensations caused by these stimuli may be reduced to greater logical consistency and meaningfulness than has previously been the case.

Throughout the past century, certain stimulus variables which should be controlled have become apparent. From the beginning it was felt that the amount of stimulating substance was a significant variable, and that it should be measured and expressed in standard units. The first measurements were in terms of the absolute amount of the substance or of its relative concentration. This variable is chemical in nature and as knowledge of chemistry has increased, the unit of measurement of the variable has become more appropriate. At present the chemical aspect of the stimulus can best be expressed in terms of the number of molecules of the stimulating substance present.

A second significant feature was not completely appreciated until recently when it was realized that control over the volume and the force of the inhalation are also very important for accurate threshold determinations. Accordingly, the subject has been relieved of the necessity to inhale or "sniff" and now merely allows a stimulus of known volume to be blown toward his olfactory area at a stated pressure.

The major variations in olfactometric instruments have been discussed, principally in light of the control achieved over the above-mentioned factors, in four groups according to the units in which the stimulus is expressed. The first consists of those techniques involving measurement in terms of amount of odorous material present or in terms of the relative concentration of this material. The second group contains the Zwaardemaker technique whose distinguishing feature was the avoidance of concentration measurements and the use, rather, of some indirect unit. In the third group are fairly recent devices which have corrected many of the errors previously made, although in no case were all of the errors eliminated. Finally, there is a description of a new technique, currently being used by the author, in which all of the specified controls have been incorporated.

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TECHNIQUES FOR THE DIAGNOSIS AND MEASUREMENT OF INTERGROUP ATTITUDES AND BEHAVIOR

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I. Introduction

The atmospheres of a labor union, a militant political organization or an interracial boys' club pose problems of research technique less violently encountered on a college campus. People under these conditions are likely to have less time to volunteer as test subjects, less ability to articulate their opinions, more downright suspicion of the investigater. Yet in such settings occur the most important social problems of our dao and the most important social efforts toward their solution. For this reason more and more social scientists are undertaking research in these settings—and research requires techniques of diagnosis and measurement.

This article will survey methods designed for or appropriate to the investigation of intergroup attitudes and behavior in community settings. The emphasis will not be upon the original functions for which these methods were employed, but upon their uses and limitations for future research with noncollegiate populations. Each technique will be discussed in connection with some study or studies in which it was used and to which the reader will be referred for additional information about the technique. Frequently, only one study will be cited in connection with a specific technique; this will be the study which we feel describes the technique most clearly or illustrates its use most adequately. It will often not be the study in which the technique was first employed. Critical comments on individual studies will be offered only where such comments could conceivably be helpful in future applications of the specific technique for which the study is cited. Results of

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studies will be mentioned only where they shed direct light on the techniques of investigation.

We shall attempt complete coverage of techniques described in the professional literature through the end of 1946. Many important contributions made recently in still unpublished studies are omitted, since complete coverage of this type of material is at present impossible. Consequently our survey cannot meet the present urgent need for some way of avoiding wasteful duplication of unpublished research efforts. A formal arrangement for prepublication exchange is indicated when studies become as lengthy and expensive as some of those now under way in the field of intergroup relations.

In our discussion of specific techniques the emphasis will be on their value in diagnosis rather than on their value in measurement. By diagnosis we mean the analysis of a state of affairs in qualitative terms, with special attention to structural characteristics and causal or conditional relationships. By measurement we mean the assignment of a particular datum to a position on some generalized dimension by means of some standardized, objective procedure. It is clear that in the study of any particular situation diagnosis and measurement are interdependent. Well conceived and carefully applied measurements can be a tremendous aid in making a detailed diagnosis; but without some initial diagnosis it is impossible to know what measurements to apply. The value of measurement in describing a situation depends ultimately on the correctness with which the structure of the situation and its crucial dimensions have been diagnosed.

All of the techniques we shall discuss yield data which are directly useful in diagnosis. But these data are typically qualitative, in the form in which they are initially collected, and their usefulness for measurement depends on some method of quantification or scaling. We shall not discuss the various possible scaling methods, since they have been clearly described in several recent reviews (**39, 53, 64**). Our classification of techniques will be according to the type of data initially collected. The order of presentation will be from the more simple and direct techniques to the more indirect and specialized ones.

II. Observation

Observation is the basic method for the study of almost every kind of social behavior. Yet if it is used carelessly, it is likely to provide data which are nearly worthless. Most contemporary studies attempt to safeguard the value of observational data by setting up a systematic procedure for making and recording observations and training the observers to follow this procedure.

An observer will always make his report in terms of some frame of reference and some set of categories. If the reports of several observers are to be combined, it is essential that the categories and frame of reference be the same for all and that they be agreed upon in advance. Naturally some a priori analysis must underlie the selection of categories according to which happenings are recorded. The value of the resulting data will be dependent on the extent to which these categories actually reflect crucial aspects of individual and group behavior.

The perceptions of the human observer may be supplemented by phonographic recording or motion pictures. But it is never possible to record every detail of a social process, and some analysis must be made in advance to determine what kinds of data are expected to be relevant.

For discussions of observational problems, and descriptions of categories for quantitative analysis of observational data, see the Lippitt study (**34**) of autocratic and democratic social atmospheres, Miller's study (**44**) of group discussions, and Loomis' study (**35**) of industrial work. Special problems arise in situations where the observer must disguise his activity and behave as a regular functioning member of the observed group. This ancient research method, newly baptized participant observation, is discussed by Loomis in another article (**36**).

Reliability of observation can be determined by comparing observational data with mechanical recording of the behavior, or by correlating results of independent observers. The latter procedure can also be used to establish reliability of interpretation. White (**61**) reports reliabilities of .80 to .86 for stenographic records of conversational data, analyzed in terms of psychological categories.

If the social process being studied extends over a long period of time, it may not be feasible to observe the whole of it. Adequate time-sampling depends on selection of intervals corresponding in some way to the time-units in which the observed activity is naturally organized. For a discussion of the problem, see Arrington (**3**).

A recent systematic evaluation of observation as a technique for studying certain group phenomena is described by Newman (**47**). The reported study yielded inter-observer reliabilities of .74 to .90, with highest agreement on the most clearly-described behavior categories. The writer emphasizes the usefulness of descriptive and narrative comment in addition to rating scales, for shedding light on differences between ratings of different observers and in general suggesting the dynamics underlying "objective" data. In addition to the more usual observational procedures, formal use was made of verbatim records of discussions in which staff members pooled their observations regarding

individual and group behavior. For events which could not be covered by a single observer (for instance, a week-end excursion of 50 or 60 adolescents) this "conference technique" served to bring out points which could not be derived from summation of individual reports.

Willcock (63) has reported on a technique known as mass-observation, which was used in England during the war for the collection of data on a very large scale. By advertising in several newspapers, the government agency responsible for public opinion was able to select literally hundreds of observers scattered throughout the country. Each observer was required to keep a diary and record every event that occurred. Everything that was seen or heard in a single day was recorded. These records were sent in to the government office at regular intervals for analysis. For data on topics of special importance, formal questionnaires were sent to the observers. For example, in planning a rationing program, the pub-going and smoking habits of industrial townspeople were studied. Two crucial factors in this technique are, of course, the accuracy of the observer's report and the representativeness of the observer sample. No attempt was made to stratify the sample of observers.

Uses and limitations of observation. The greatest advantage of observational techniques is their directness. Interpretation is usually most straightforward and explanation most realistic when a phenomenon is investigated on the level at which it occurs.

Observation is a very flexible method, adapted to almost any type of inquiry. If the inquiry concerns matters which people are anxious to conceal from outsiders, participant observation may be the only possible procedure.

Observation differs from testing and interviewing in that it does not require people to modify their behavior in any way for the benefit of the investigator. They may not even be aware of his presence. Consequently there is a minimum of distortion introduced by the investigative process. However since the observer exerts no control over the subjects' actions, the volume of irrelevant material can be huge. The complexity of even the simplest intergroup phenomena gives observational data in this field both a tremendous richness and a tremendous resistance to any kind of meaningful and manageable organization.

III. Personal and Public Records

The analysis of records may be direct or indirect, depending on whether the statements in the records are taken at their face value as reports of attitudes and behavior, or whether these statements are interpreted in some way as indicating attitudes and behavior other than those which are directly stated. All historical study depends primarily on the analysis of records. The problem of the "authenticity" of a particular document is essentially the problem of whether it can be

analyzed directly, or whether the only possible interpretation of it is an indirect one.

A good example of the direct analysis of public records in the field of intergroup attitudes and behavior is the study by Hovland and Sears (28) of the relation between frequency of lynching of Negroes and various socio-economic factors.

Runner (54) analyzed the diaries of two adolescent girls and developed categories of intimacy which made possible diagrams of their relations with their friends. Concentric circles represented the various degrees of intimacy within which the relationships fell. While not a particularly economical procedure, this could under some circumstances be a more valid way of evaluating past relationships than relying on the subject's possibly distorted recollections. In situations where attitudes may change rapidly (for instance in an Army hospital ward where some white soldiers meet Negroes on an equal and close basis for the first time) last week's careless diary entry may be of more value than the best-intentioned attempt, in today's interview, to reconstruct vanished first impressions.

The most widely used form of indirect record analysis is the method which Lasswell and others have called "content analysis." This method consists essentially of counting the frequency with which various words, phrases, or other "content units" occur in a particular body of material and relating these frequencies to one another or to the frequencies of similar content units in another body of material. The results can then be interpreted as indicating certain attitudes or intentions on the part of whoever produced the material being analyzed. Content analysis was originally developed for the description and interpretation of propaganda, but it can be applied to almost any kind of meaningful verbal material.

Severson (56) tallied employment advertisements stipulating race, nationality, or religion for prospective employees in a Chicago newspaper for each year from 1872 to 1937, and sought correlations between sociological trends and peaks in discrimination as measured by this criterion.[2] Hartley (22) studied classified advertisements in the New York Times for the first Sunday in each of the months of January, April, July, and October for the years 1930 to 1939. Those referring to race, nationality, and religion were tallied, and the percentage of such refer-

[2] An example of possible pitfalls in the use of such records is the failure of this study to take into account the changing number of Negroes in Chicago, a trend which overshadowed all others during the period under consideration. In the early years nobody expected that a Negro might show up in response to an advertisement.

ences occurring in each type of advertisement was computed. The analysis brought out not only temporal trends, but also the relative "salience" of ethnic factors in the various kinds of social relations corresponding to the different kinds of advertisements. The Commission on Law and Social Action of the American Jewish Congress (66) recently made a content analysis of the news stories dealing with minority groups which appeared in a particular newspaper, and on this basis challenged the fitness of the paper to acquire a radio permit.

White (62) has described a method of analyzing the content of personal records which he calls "value analysis" and has demonstrated its use with a published autobiography. White's method is designed to reveal as much as possible about the motivation of the author of whatever document is analyzed.

Uses and limitations of personal and public records. Written records are the only means available for the study of intergroup attitudes and behavior which have occurred in the past, unobserved by anyone who is now available to the social scientist for questioning. The direct analysis of records is useful to the extent that the records deal with the subject about which information is being sought and to the extent that the statements in the records can be taken at face value. The indirect analysis of records provides valuable information about the person or persons who produced the records, but it cannot usually yield reliable information about the attitudes or behavior of anyone else.

IV. Specific Performances

Frequently, action programs aimed against intergroup antagonism have among their objectives more concrete and specific results than any so far discussed. For instance, an employer may be interested in the effect of a new non-discriminatory hiring or upgrading policy on employee morale as reflected in production. A political pressure group may want to know which of two alternative tactics yields more signatures on anti-poll-tax petitions to Congress. To the head of a recreation center the success of a certain way of handling intergroup tension in boys' clubs may seem to be most crucially tested by fluctuations in the voluntary attendance of club members. Money contributions are a readily measurable and psychologically acid test of the success of an intercultural organization's appeal for support.

Elliot (12) reports a comparison between two methods of interesting students in coming to a college where the criteria for comparison were the number of inquiring letters received and the number of actual enrollees.

A study by LaPiere (31) points up interestingly the difference be-

tween actions and verbal statements as indices of attitude. In travels in the U. S., he and a Chinese couple stopped at 66 sleeping places and 184 eating places and were refused service only once. Afterwards, the proprietors of these places were mailed questionnaires asking whether they would "accept members of the Chinese race as guests in your establishment." Ninety-three per cent of the restaurants and 92 per cent of the hotels, etc., said that they would not serve Chinese people. A control group of places which had not been visited gave analogous questionnaire results. Since both face-to-face behavior and answers to letters were instances of actual responses to situations, it is pointless to argue their relative validity as measures of prejudice; which would be a better guide to a specific action program would depend on the aspect of prejudice at which the program was aimed.

The Commission on Law and Social Action of the American Jewish Congress has used telephone surveys (67) to evaluate the effectiveness of a New York State law in curtailing discriminatory practices by employment agencies. The technique consisted of phoning a representative sample of employment agencies and posing as a prospective employer in search of an employee of specified ethnic background. Compliance or refusal on the part of the agency was recorded.

The Committee on Racial Equality (6) uses a special method for experimental testing of Jim Crow practices in various social settings. A mixed group of Negro and white people go as ordinary citizens to the place in question and request hotel, restaurant, or railway accommodations. Records are kept of the treatment received.

Uses and limitations of specific performances. These techniques have the great advantage of naturalness and immediate relevance to action objectives. However, they can be extremely misleading if used in isolation, without knowledge of the social context and the psychological dynamics of the behavior reported. For instance, the frequency of conformance with a non-discriminatory employment practice proves nothing in itself about the depth and permanence of underlying attitudes, and provides no basis for prediction of what would happen should unemployment become widespread. It does not hint at the variety of motives which, under present conditions, produce the uniform behavior now added up into a single number but which might under slightly different conditions result in a bewildering assortment of different behaviors.

Similarly, leaders of political groups would be fated for severe disillusionment if they took applause and money contributions as a complete measure of the extent to which their programs were rooted in the public mind and will. The status of labor unions and progressive groups in just pre-Hitler Germany is a case in point.

V. Sociometry

Sociometry measures intergroup relations in terms of frequency of certain behaviors toward actual people. The behavior most commonly studied is choice of companions. This may be recorded as it occurs in the ordinary course of social events, or a choice situation may be specially arranged for investigation. Subjects may be asked to choose not companions but leaders, group representatives, etc. Or they may be asked to indicate which members of the group are most cooperative, most aggressive, or most anything which is positively or negatively valued. Frequently subjects also indicate the people whom they would *least* like to have for companions, etc.

Loomis and Davidson (**38**) used a sociometric technique to measure increased social amity among three initially hostile groups from different geographical origins then living together on a rural resettlement project. Each family gave the name of the five families which visited at its home most frequently. The measure of "in-grouping" was the ratio of actual to chance inter vs. intra-group visits.

Criswell (**9**) applied sociometry to the study of racial cleavage among grade school children in mixed Negro-white classes. Each child was asked to choose two members of his class beside whom he would like to sit. Deviations from a chance distribution of choices in the direction of segregation were computed.

Loomis (**37**) studied ethnic segregation patterns among English-speaking and Spanish-speaking high-school students in the Southwest. Each student wrote the names of those he played with most at school, and those he played with most on week-ends and holidays. The factor of family relationship was controlled by asking the subjects to indicate which of those named were relatives, and a "self-preference ratio" was computed for each group. Data comparing week-end playmates with school playmates, which might have led to some conclusions about the role of neighborhood segregation in maintaining segregatory school patterns, were not presented. Part of the same study was a beauty contest in which each child indicated the best-looking boy and girl in the class. That this technique gets at a quite different psychological process is indicated by lower self-preference ratios in the beauty contest than in the choices of playmates. For general purposes, the beauty contest technique has the advantage of justifying itself in the eyes of subjects rather than appearing as an imposition from the investigator, whose purpose may then be guessed at. Decreased self-preference ratios in judgments of physical beauty might well be one index of decreased prejudice resulting from favorable intergroup contact.

Hartley (23) used a sociometric test with pre-adolescent boys, requiring subjects to name others in the group whom they would choose as companions for each of a variety of different social activities. The list included ten activities, such as "eat lunch with," "loaf around with," "play in the park with," "have come to a party at my house." While not originally designed for the study of intergroup relations, this kind of test would have obvious advantages over cruder measures in revealing patterns of social relations among members of different ethnic groups. It distinguishes among the varying kinds of associations lumped together in answers to a single broad question such as "Whom would you like for a friend?"

Uses and limitations of sociometry. Before segregated patterns of choices can be interpreted as indicative of prejudice in any psychological sense of the word, the factor of familiarity must be ruled out. People tend to seek out others whom they already know, regardless of skin color, and segregated neighborhood patterns could lead to segregated school patterns without any element of individual rejection being involved. Of course, any measure of segregated practices, regardless of psychological significance, is of value provided it is properly interpreted, since social segregation is likely to cause or help maintain prejudice even where it does not result from prejudice.

Sociometric data revealing the absence or diminution of segregation in a given group must always be interpreted cautiously, since the evidence reflects relations among specific individuals, who may or may not regard each other as representatives of their respective ethnic groups. The value of sociometry in assessing the success of an action program also depends on the relevance of the sociometrically measured relationships to the objectives of the program. For instance, the success of a union's anti-prejudice drive might be more appropriately measured by the increased readiness of whites and Negroes to work together on the same union committees than by their increased readiness to play baseball on the same teams.

VI. Interviews

Interviews on intergroup attitudes may range in depth from verbally administered opinion questionnaires to psychoanalytic explorations of the deepest emotional functions of prejudice. Most polling agencies have at one time or another asked questions about various identifiable social groups. Sometimes the questions call for simple "Yes" or "No" answers—for example, "Do you think that the Jews have too much power in the United States?" Sometimes they are "open ended"—for example, "Are there any groups of people you think are trying to get ahead at the expense of people like you?" (with the follow-up question, "What groups?") Sometimes a number of different questions are asked in the same interview and the answers combined as in a written ques-

tionnaire. Flowerman and Jahoda (13) discuss general problems involved in polling intergroup attitudes. McNemar (39) stresses the value of a battery of questions.

Lazarsfeld (32) has developed a method involving repeated interviews over a period of time with a panel of informants selected as representative of the population. Its advantages are its applicability to issues and processes which develop over time, and the ease of interviewing respondents to whom practice has lent skill in formulating opinions. Its main drawback is that the panel in becoming more self-conscious and articulate may lose its representativeness. The seriousness of this factor depends on whether self-awareness is likely to have a crucial influence on a person's response to the particular issue or process being studied.

Merton and Kendall (43) discuss the technique and functions of a particular type of intensive interview aimed at evaluating the effect of a specific experience (moving picture, discussion, book, experiment) on certain attitudes of the subject. This kind of interview is particularly pertinent to action research, since it is focussed as much on the characteristics of the would-be attitude-changing action medium as on the attitude itself, discovering which specific aspects of the "stimulus situation," as the authors call it, were responsible for which specific aspects of the resultant attitude change. Properly administered (and rules for its proper administration are amply illustrated in the article), it yields a type of information which could not be obtained from pre- and post-testing plus independent content analysis. No attempt is made to analyze results quantitatively. They are used to help interpret questionnaire data for which explanations might otherwise have to be conjectural, and to provide hypotheses for subsequent quantitative testing.

Frenkel-Brunswik and Sanford (15) used intensive interviews in conjunction with a questionnaire and a modified Thematic Apperception Test. The goal of the interview was to get as broad as possible a picture of the subject's personality, general approach to life, attitudes toward authority, social and political issues, status, money, etc., for the purpose of seeing how attitudes toward minority groups functioned in these larger systems. Findings from these interviews were presented qualitatively in descriptions of characteristic personality patterns correlated with high and low anti-Semitism. On the basis of the interview data questionnaire items were developed relating to conventionality, family attitudes, superstition, ego strength, etc., which were interpreted in the light of the interview material. Correlations of these question-

naire items with those on ethnic attitudes substantiated, in turn, the interview findings.

The practice of classifying qualitative material into certain formal categories can also be applied to the intensive interview. Child (7) describes a semi-standardized use of intensive interviews in a study of the acculturation process in second-generation Italians. On the basis of life-history interviews and participant-observation in various social activities, a list of topics was formulated, each of which was posed and phrased by the interviewer in a uniform way. To enhance reliability of interpretation, criteria for analysis of responses were formally described before the analysis was begun.

Dollard's (11) criteria for the life history are relevant both for studies where life-histories must be taken and as a general example of the kind of plan that can be drawn up to insure that an intensive interview or a series of them will cover certain minimum areas of information.

Uses and limitations of interviews. Like observation, interviewing is a technique of great flexibility which can be used to investigate almost any type of problem. Interviewing has the advantage over observational techniques of being able to provide a much greater quantity of information about special topics in which the investigator may be interested, including events which have occurred when no scientific observer was present. It has the disadvantage that its data may be distorted by the reaction of the subject to the interviewer and by the subject's bias concerning events which the interviewer is trying to get described in objective terms.

At their most structured extreme, interviews have the advantage over written questionnaires of being applicable to groups with low reading ability. In their most unstructured form they have the advantages and disadvantages of the projective techniques which will be described later. Almost any type of interview has the advantage over a test or questionnaire of allowing easy access to the individual whose intergroup attitudes or behavior are to be studied. It is not necessary to inveigle him into a test-taking situation, there is little difficulty in getting him to follow instructions, and there is little danger that any test items will be omitted. But these benefits are secured through the social stimulation which the interviewer exerts on the subject and the fact that it is the interviewer, not the subject, who has the job of recording the responses. Consequently, the influence of the investigator on the data collected is likely to be maximal, for a given type of data, when the data are secured through interviews.

VII. Questionnaires

In this category we include all the paper-and-pencil tests consisting of series of questions, statements, etc. The subject may be given a blank space in which to write his answer, or he may be asked to choose one of a series of alternative answers which are presented. The latter

procedure is most commonly used, since it facilitates numerical scoring. We shall discuss each of the main varieties of questionnaire separately.

Preference questionnaires. These provide data on the relative popularity of various groups. Either a rank-order, a paired-comparison, or a rating technique may be employed. Guilford (**19**) used the method of paired comparison, presenting fifteen races or nationalities in a hundred and five pairs, and asking the subject to choose which one of each pair he would prefer to admit into the country. The order of preference thus obtained correlated .97 to .99 from one university to another.

Meltzer (**40**) used the same technique with grammar-school children, except that the criterion of preference was which group in each pair the subject preferred to associate with. The order of preference correlated .95 with that obtained by an absolute rating technique in a later study (**41**), in which subjects indicated degree of like-dislike on a 5-point scale for each group.

The only thing which a preference questionnaire reveals about an individual's attitude toward a particular ethnic group is that it is more or less favorable than his attitude toward some other ethnic group. Shifts in the popularity of the various ethnic groups can take place against a background of unaltered prejudiced ways of thinking; and, conversely, drastic increases and decreases in tolerance can occur without affecting the order of preference.

Stereotype questionnaires. Many investigators have used this type of questionnaire. Katz and Braly (**29, 30**), for example, instructed each of their student subjects to choose five stereotypes for each of ten ethnic groups. The popularity of a stereotype, as applied to members of a particular ethnic group, was indicated by the percentage of students who chose it. The extent of agreement among subjects on their stereotyped picture of a given group was indicated by the number of different stereotypes which were required to include 50 per cent of the choices made. This number ranged from 4.6 for Negroes to 15.9 for Turks. It was possible to determine an order of preference for the ten ethnic groups by means of the relative favorableness or unfavorableness of the stereotypes assigned to them. This order of preference was almost identical with that obtained by asking another group of students from the same college to rank the ten ethnic groups directly in terms of their preference for them.

Blake and Dennis (4) used a somewhat different procedure to trace the growth of stereotypes for Negroes over the elementary-school and high-school years. Subjects were required to compare Negroes and whites on a variety of traits (for example: "Who is more easy-going?"). For each trait, a "preponderance index" was computed consisting of the difference between the percentage of subjects responding "white" and the percentage responding "Negro." Changes in the popularity of a

stereotype from one grade to the next were indicated by changes of the preponderance index for that trait.

Stagner and Osgood (**59**) report a procedure which involved rating each of eight national groups along a number of dimensions (e.g. kind-cruel, strong-weak, fair-unfair, etc.). Several of comparable student samples were tested at intervals during the historically crucial period between April 1940 and March 1942. Changes in stereotypes could then be studied in terms of shifts in absolute level of approval (i.e. over-all predominance of ratings near the favorable ends of the various dimensions of judgment) and also in terms of shifts in the pattern (i.e. relative weights) of perceived characteristics for a given group.

Stereotype questionnaires are primarily useful in estimating the prevalence on a mass basis of beliefs about different groups, and in tracing changes in the pattern of beliefs over time. Change in stereotypes concerning Negroes, for instance, might be a good criterion for the success of an educational campaign which involved introducing prejudiced whites to cultured Negroes of high socio-economic status. However, knowledge of the content of an individual's stereotypes does not in itself tell us much about how he will behave toward members of another social group, nor even how he usually thinks and feels about them. The emotional implications of a particular stereotype are quite different for different individuals; and there are some individuals who react to members of other groups with only a minimum dependence on their stereotypes concerning the groups of which these people are members.

Situational questionnaires. In recognition of the imperfect correspondence between beliefs about the characteristics of different groups and beliefs about the proper way to behave toward them, several investigators have developed attitude tests based on behavior situations. In this type of test the individual is presented with a hypothetical real-life situation and asked either to choose one of several alternate behaviors or to indicate degree of approval of a given behavior. Rosander (**52**) developed such a questionnaire in a study of prejudice toward the Negro. Typical items are: "You are reading in a public library. A Negro comes in and sits down beside you." "You attend a conference at a hotel which will not allow Negro delegates to register." Multiple-choice responses to each situation were rated on a 12-point scale by 50 judges, and the median scale value assigned to each alternative became its score value on the test. Alternate forms yielded high reliabilities, and the test discriminated significantly between Northern and Southern university students.

Harlan (**21**) constructed a similar test for use in a study of anti-Semitism. His test items were real-life situations in each of which prejudice was expressed. Subjects stated their approval-disapproval of the prejudiced act described in the story on a five-point scale. The sum of these responses was taken as a measure of their prejudice. Split-half

reliabilities were high. The test discriminated significantly between Jews and non-Jews, and correlated .66 with self-ratings on attitude toward Jews.

Schuler (55) developed for adolescent subjects a series of hypothetical case situations around the segregation issue in housing, each followed by five alternative responses forming a continuum of approval-disapproval toward racial segregation in that particular situation. Each item was also followed by the question "Why do you think so?" Reasons given by the subjects aided qualitative evaluation of their scores.

Davis (10) used a kind of situational test for getting at anti-Negro attitudes in Negro college and grade-school students. A typical item follows: "Johnny was a little colored boy whose mother was very poor. One day she asked him to stay at home and work in the garden. What do you think Johnny did?" Davis actually provided his subjects with a series of answers from which to choose, but a free response technique might equally well be employed.

The strongest argument for the situational type of questionnaire is that it presents the subject with the sort of concrete choices he is likely to encounter in real life, and that consequently his responses indicate his probable future behavior more directly than do his responses to other types of questionnaires. Even so, the experiment of LaPiere cited above indicates that the contrast between questionnaire behavior and "real life" behavior may be very great.

Social distance questionnaires. The social distance test is really an abstract and generalized type of situational questionnaire. The subject is presented with a list of hypothetical relationships involving various degrees of intimacy with himself and asked to indicate each relationship to which he would admit the members of a particular ethnic group. In the original form of the test used by Bogardus (5), the relationships are: to close kinship by marriage, to my club as personal chums, to my street as neighbors, to employment in my occupation in my country, to citizenship in my country, as visitors only to my country, would exclude from my country. Various statistical procedures are used to derive from the individual's responses a quantitative measure of his "social distance" from the ethnic group in question. The ranking of different ethnic groups according to their social distance has been shown to correlate very highly with their ranking according to preference questionnaires.

Murphy and Likert (46) added up the social relationships to which members of 21 ethnic groups would be admitted, to provide a generalized measure of "tolerance toward nations and races." The split-half reliability of this measure was .94 in one student group and .95 in another. Thus, if an investigator knew the total or average social distance for a particular individual of ten ethnic groups drawn at random, he could predict with great accuracy the average social distance for that individual of another ten groups drawn at random without any necessity of knowing what the particular groups were.

Hartley (22) demonstrated the same point in another way by asking his subjects to respond not only to the usual ethnic groups but also to three imaginary groups—Danireans, Pireneans, and Wallonians. He found that correlations between the mean social distance scores for 32 real groups and for the three imaginary groups ranged in five American colleges from .78 to .85.

The social distance questionnaire provides a superficial but (for the amount of time it takes to administer) extremely comprehensive view of a subject's attitudes toward various ethnic groups. This comprehensiveness is gained by sacrificing the concrete detail which lends an air of realism to most other situational questionnaires. The factor of "general tolerance" which emerges from the social distance questionnaire is probably a fairly central one, for college students at least. Murphy and Likert (46) showed that it correlates highly with several measures of social and economic radicalism.

Opinion questionnaires. The typical opinion questionnaire in this field consists of a list of statements about the members of one or more social groups. The subject indicates agreement-disagreement with each statement. Sometimes the statements are phrased in the third person ("Jews can't be trusted"), sometimes in the first person ("I believe the Negro deserves the same social privileges as the white man"). A less common practice is to phrase the items in the form of questions ("What proportion of Mexicans are criminals?") and give the subject a number of alternative answers from which to choose. Or the subject may be required to phrase his own response—e.g., "Nearly everyone has the feeling that certain religious, racial, national, or economic groups are uncongenial to him. Name the groups which you regard as personally uncongenial and tell very briefly why you feel each one to be so" (2).

Peterson and Thurstone (48) used opinion questionnaires to evaluate the effects of motion pictures on the intergroup attitudes of high school students. Their questionnaires included an "Attitude Test toward the German People," an "Attitude Test toward the Chinese," and Hinckley's test of attitudes toward the Negro. Each questionnaire was scored according to Thurstone's method of equal-appearing intervals. All scores showed before-and-after shifts in the directions expected from the content of the movies.

Levinson and Sanford (33) developed an anti-Semitism questionnaire using two types of opinion items. One type consisted of statements about alleged Jewish characteristics, such as: "One general fault of Jews is their over-agressiveness, their tendency always to display their Jewish looks, manners, and breeding." The other type consisted of statements about possible actions with reference to Jews, such as: "Anyone who employs many people should be careful not to hire a large percentage of Jews." The questionnaire was scored according to Likert's method of summated ratings. In a group of non-Jewish women college

students the reliability of the total score was found to be .98. An intensive personality study by Frenkel-Brunswik and Sanford (**15**) showed that high and low anti-Semitism, as measured by this scale, were related to quite distinct types of character structure.

Pugh (**50**) describes a questionnaire on attitudes of Negroes toward Negroes which consists of statements such as "We are inferior to white people because our ancestors were savages and later slaves," and "If I had the choice I would be white rather than Negro." The questionnaire was used to compare the adjustment of Negro students in mixed and segregated high schools.

Grice and Remmers (**18**) have prepared a series of statements which can be used to investigate opinion toward any ethnic group.

Perhaps because it is so easy to construct great numbers of opinion items and administer them to student populations, the main interest of workers with this type of questionnaire has been in statistical methods of item selection and scaling rather than in the phrasing of individual items or the qualitative interpretation of responses to them. The standard methods of scaling and item analysis are reviewed in the references cited at the beginning of this article (**39, 53, 64**).

Self-rating questionnaires. These differ from opinion questionnaires in that the subject is asked to make statements about how he feels concerning members of a particular group or about his experiences with regard to them instead of indorsing statements about the supposedly "objective" characteristics of the group. Riker (**51**) asked college students to indicate their degree of favorableness-unfavorableness toward Negroes and Germans on an 11-point graphic self-rating scale. They similarly indicated their attitudes on a number of social issues. The self-ratings had repeat reliabilities ranging from .50 to .86. Correlations with scores on Thurstone-type questionnaires regarding the same social issues and ethnic groups ranged from .55 to .84.

Allport and Kramer (**2**) used a questionnaire with a variety of opinion and self-rating items. Some of the latter items were: "Have you ever known a Negro with about the same education as you have?" ("Yes" or "No" answer); "Certain people are more prejudiced than others. How would you rate yourself in comparison with the average person?" (five-point rating scale); and "What do you consider to be the most important thing you have learned in school about minority groups?" (free response). For their analysis the authors constructed a "prejudice score" from their opinion items and correlated this with each of the self-rating items. As they expected, the correlation with self-rating on prejudice was not very high.

The range of a self-rating question can be extended until it becomes a "topical life history" in which the subject is asked to include everything he can remember concerning his intergroup attitudes and behavior. The interpretation of self-ratings involves all of the problems

encountered in the interpretation of personal records. For a detailed discussion of these problems, see Allport (1).

Other questionnaires. Stagner (58) reports a procedure which allows the subject to express dislike of certain social phenomena by literally crossing out stereotyped words referring to them. A list of controversial terms (such as "Birth Control," "Communist," "Evolution") was presented with the instruction to cross out disliked terms. Results with this list were fairly reliable: rank-orders of the items correlated highly from group to equivalent group, individual subjects marked similar terms fairly consistently, and although split-half reliability was low this is not significant since the list was not intended to be internally homogeneous. The author argues for the speed and simplicity of this technique, its "harmony with our cultural patterns for dealing with such situations" (i.e. disliked phenomena), and the probability that it reaches deeper levels of prejudice than would be expressed in articulate opinions. Although Stagner's list is not focussed on intergroup relations, it would be easy to construct such a list.

Gilbert (17) attempted to measure a cognitive dimension of prejudice in eleventh graders with a series of problem situations on racial issues offering the option of following the reasoning to a logical conclusion or choosing a conclusion dictated by a preconceived bias. Morgan (45) used a similar method to investigate attitudes toward the Japanese.

Zeligs (65) employed a very free open-ended question procedure with sixth grade children. The names of 38 races and nationalities were put on the blackboard, and children were told to write the most interesting true sentence they knew about each group. Only about one minute per sentence was allowed, to encourage spontaneous responses. Zeligs analyzed her material qualitatively, but quantitative ratings of attitudes could easily be derived if they were desired.

Uses and limitations of questionnaires. The great advantage of questionnaires is the ease with which they can be administered to cooperative subjects, especially if the subjects are assembled in groups. For investigators interested in measurement, questionnaires have the further advantage that it is possible to include a large number of items without greatly increasing the difficulties of administration and scoring. This frequently leads to high reliability of the scores.

On the other hand, all questionnaires require subjects to possess at least a minimum ability to read and follow directions, and free response items require in addition some facility in verbal expression if the results are to have any value. The dangers of misinterpretation of items and falsification of responses are probably greater with questionnaires than with other diagnostic techniques, since the group-administered questionnaire does not provide opportunity for the investigator to observe the subject closely as he is responding, or to ask him additional questions to check up on doubtful points. Where accurate diagnosis of individual subjects is important, the safest procedure is to follow up the questionnaire with interviewing, observation, or test situations.

VIII. Pictorial Techniques

In work with the attitudes of young children, extensive use has been made of pictures. Horowitz (25) developed a test consisting of twelve photographs of boys, four white, four light Negro, and four dark Negro, which the young subject ranked in order of preference and from which he selected individuals whom he would like to sit next to in the street car, in whose class he would like to be, with whom he would like to play ball, etc. A later revision of the test included more pictures and questions involving impersonal description as well as personal social choice. There were instructions to "show me" those that: "Live in a dirty house," "Your folks would not let you play with," "Are most stupid," etc.

Horowitz also used photographs of groups of boys in posed play situations, some groups all white and some mixed white and Negro. Subjects were asked whether they would like to "join in," and the difference in willingness to join all-white vs. mixed groups was taken as a measure of prejudice.

Later Horowitz (26) developed a technique for comparing race with sex, age difference and socio-economic status as a category according to which people are classified. He presented groups of five pictures, and asked young subjects to select from each group the picture which did not belong. Pictures were arranged so as to force a choice between two kinds of categorization. For example, a page might include three white boys, one Negro boy, one white girl. In excluding one, the child must choose either race or sex as his guiding principle. This was supplemented by interviews, asking "Would you rather play with . . . ," followed by pairs such as "Poor white boy-Rich colored boy," etc.; the four factors were used in all possible combinations.

Helgerson (24) employed a similar technique pitting race against sex and facial expression as criteria for choice of playmates. She used sets of photographs of Negro and white children, each racial group including a laughing and a sober representative of each sex. The pictures were paired in different ways, with sex, race, and facial expression as variants. Pre-school subjects were asked to choose a playmate from each pair, and the relative significance of the three factors was computed from results. This technique seems promising both for genetic studies and for measurement of individual differences in attitude.

Ruth Horowitz (27) studied the strength of race as a factor in the self-identification of nursery-school children by the use of (a) a multiple choice procedure in which the child is shown pictures of Negro and white children, a chicken, and a clown, and asked "Which one is you?"; and

(b), a procedure in which the child is shown portraits one at a time and asked "Is this you?"

Clark and Clark (8) used essentially the same technique in a study of the emergence of racial self-identification in Negro pre-school children. That choices actually reflect degree of racial self-identification is indicated by a trend toward increased identification with the Negro child with increasing age.

Hartley (22) presented a set of photographs of boys and girls of college age to college-student subjects with directions to sort them into piles on any basis desired. Four resortings were required, and the criteria for classification chosen by the subject were analyzed. For group administration similar photographs were presented, followed by directions to list descriptive statements about the pictured individuals. The proportion of statements referring to ethnic characteristics was taken as a measure of the "salience" of this principle for classifying people in the subject's system of social orientation. "Ethnic salience" was not clearly correlated with tolerance, as measured in this study by a social distance scale.

Uses and limitations of pictorial techniques. For certain special types of investigation pictorial techniques are extremely useful. Like questionnaires, they are easy to administer and can be constructed in such a way as to yield objective and readily quantifiable results. Verbal comprehension is needed only to the extent of understanding the general test instructions—an advantage over questionnaires—and the purpose of the test can be more completely disguised, thus reducing the possibility of deliberate falsification. However the types of responses that can be investigated by pictorial techniques are more limited than those which can be studied through questionnaires, and there are only a few social groups which can be clearly identified pictorially.

IX. Projective Techniques

The essential characteristic of a projective technique is that responses are not taken at face value—that is, with the meaning which the subject presumably would expect them to have if he understood the test directions—but are interpreted according to some psychological theory about the subject's responses in the test situation. It is consequently possible to use any one of the interviews, questionnaires, or pictorial tests already described as a projective technique if the responses to it are interpreted projectively; however there are certain types of data which are especially suitable for this type of interpretation, and investigators who intended to interpret responses projectively have for the most part preferred to use special testing techniques to obtain the data they needed.

Proshansky (49) used a procedure adapted from Murray's Thematic

Apperception Test to study attitudes toward labor. Ambiguous pictures of situations involving labor were exposed for five seconds each, and college subjects were asked to write for two and one-half minutes on what they thought each picture represented. From these stories three judges inferred attitudes toward labor and rated them on a five-point scale. The ratings correlated .87 and .67 in two groups with scores on a questionnaire of labor attitudes.

Frenkel-Brunswik and Sanford (15) used four thematic pictures especially aimed at racial attitudes as part of their study of personality factors in anti-Semitism. The pictures were of "Jewish looking people in a poor district," "an older Negro woman with a younger Negro boy," "a young couple in zoot suits," and "a lower class man accosted by a policeman wielding a nightstick." Subjects were told that this was a test of imagination and asked to write a story about each picture. Data were interpreted qualitatively, with emphasis on the form of the attitudes toward minority group members and the role of these attitudes in different kinds of personalities. These investigators also used direct questions such as "Whom do you most admire?" and "What might cause a person to commit suicide?" Answers were correlated with scores on the anti-Semitism scale developed by Levinson and Sanford (33) and interpreted in terms of hypotheses about the typical prejudiced and unprejudiced personality structure.

Fromme (16) presented five political cartoons, each with four alternative captions judged by the author to represent a full range of pro and con opinion. The subjects were required to choose the most appropriate caption for each cartoon. The choice was taken as a measure of attitude, and the discussion provoked by the procedure provided diagnostic data for projective interpretation.

Haggard (20) studied the general attitudes of young children with a projective technique using comic strip characters. The child was asked to name his favorite comic strip hero, then became the author and told how his hero would act in given situations. This same approach could be applied to hypothetical intergroup situations.

Temple and Amen (60) describe a projective technique for use with very young children. A series of pictures is presented depicting a central character, a small child of ambiguous sex, in a variety of situations (swinging, eating alone, watching father play with younger sibling). In each of these pictures, the central character's face is left blank. The subject is given two paper faces, a happy one and a sad one, and requested to place one of them on the child in the picture and explain the reason for his choice. The series of pictures used was intended to reveal

crucial areas of personality, and yielded data quite rich in this respect. This technique might also be used with pictures of intergroup situations.

Shor (57) reports on a very flexible instrument which is similar to the classic word-association technique. It consists of the beginnings of sentences, which the subject is asked to complete. Shor's list, for investigation of general personality problems, includes items like "Today, I . . . ," "If only my mother . . . ," "My nerves . . . ,". No standardized treatment of results is reported, but the technique is said to yield a wealth of diagnostic material. This kind of test is readily adaptable to the study of intergroup attitudes. Items such as "If only the Jews . . . ," "The Negroes I know . . . ," suggest themselves immediately.

A comparatively recent development as a projective technique is the psychodrama. The method requires that the subject act out behavior as he would in real life situations. The investigator, much like an interviewer or observer, records this behavior in the conventional manner. Other participants in the drama—called "auxiliary egos"—take intimate parts like that of the subject's mother, father, or that of the subject himself. A comprehensive summary of the uses and meaning of psychodrama is given by Franz (14).

While the use of data was not entirely projective, it seems convenient to include in this section Hartley's investigation (22) of personality correlates of tolerance in college students. Self-analytic personality sketches were written by the subjects, who were guided by a list of topics to be covered. Some of these were frank invitations to fantasy (e.g. "What would heaven be like?"). The topics also included skills, interests, people and situations liked and disliked, etc. Responses were analyzed for what they revealed of basic personality traits and related to tolerance as measured by a social distance scale.

Uses and limitations of projective techniques. Projective techniques are primarily valuable for probing attitudes of which a subject is unaware. Such attitudes may sometimes be inferred from the subject's behavior in the ordinary course of events, but it is usually necessary to set up special testing or interviewing situations if one is to diagnose them with any assurance. Even with special test situations and valid theories about how subjects respond to these situations, projective interpretations can be grievously in error. Careful investigators use more than one kind of testing or interviewing situation to elicit data for their projective interpretations, and arrange to have independent interpretations made by different individuals to check on reliability.

X. Conclusion

In this review we have discussed methods of diagnosing and meas-

uring intergroup attitudes and behavior from the standpoint of the various possible techniques of data collection. A completely adequate treatment of this field would also include a systematic discussion of the most important variables which need to be measured, plus a discussion of the techniques of collecting and scaling data most suitable for the measurement of each. But this discussion would have to be based on a thoroughly adequate analysis of the major dimensions of intergroup attitudes and behavior, and such an analysis has not, as yet, been made.

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BOOK REVIEWS

KINSEY, A. C., POMEROY, W. B., AND MARTIN, C. E. *Sexual behavior in the human male.* Philadelphia: W. B. Saunders, 1948. Pp. xv+787. $6.50.

This book is based on interviews with over 12,000 persons, of whom 6,300 were males and 5,300 were white males. It is the first report of a project to which 100,000 of the American population will (it is hoped) contribute their histories. As further material is obtained it is planned to present such volumes as "Sexual Behavior in the Human Female," "Sexual Factors in Marital Adjustment," "Legal Aspects of Sex Behavior," and "Sex Education."

Spurts of scientific progress follow the invention or perfection of a new method or a brilliant and intelligent recombination of hitherto unrelated facts. This study follows the perfection of a method of interviewing and recording which permits of a new high mark in the accuracy of behavior histories. Since the method will become a standard procedure in psychological research certain features deserve comment.

The method of coded checksheet recording of an interview is a happy solution to an old and troublesome problem. Questions and answers proceed in a rapid-fire fashion. Each topic is followed through in its relevant ramifications and in the form of a natural conversation. There is no uncertainty, hesitation or seeking what topic should be followed next. As the interview goes on, an accurate record of responses is being put down in such a fashion that it can be quickly and completely transferred to IBM sorting machine cards. The entire record is visible so that the interviewer can instantly check the variety of the material which he has previously recorded and be aware of his omissions. The record of the interview can be seen by the person giving the information so that he has the visible assurance that his answers are recorded in such a fashion that no one unfamiliar with the code can interpret the record. Reliability measures can be empirically determined by the accumulation of additional histories which either substantiate or fail to substantiate the particular relationship under investigation. The methods used in this study provide five or six ways which indicate validity. No one of the procedures is proof positive but their combination provides a degree of certainty far beyond that ordinarily obtained in psychological research. This new method has great possibilities for a wide variety of psychological experimentation and test construction.

Kinsey became interested in the problems of sex behavior because his students asked him, a Professor of Zoology, many honest and seemingly simple questions for which he could find no adequate answers. Preliminary interviewing from which he hoped to obtain information rele-

vant to these questions revealed much variation among the answers. The more histories he collected the more apparent it became that nothing said hitherto had much relation to the actualities of human sex behavior. Taxonomy, Kinsey's speciality, is primarily concerned with the measurement of variation in a series of individuals. Kinsey had studied populations of more than 100,000 individual insects in his previous research. Hence he was not overwhelmed by the variety of the answers or by the apparent necessity of studying some thousands of humans and setting down in a systematic fashion organized knowledge relevant to human sex behavior which would give the answers he sought. There has resulted from the analysis of these 6,300 histories more information about male sex behavior, more new facts, more new relationships made clear than ever existed before. But, as is always the case, many new questions which are raised go unanswered. Kinsey thinks that systematic analysis of 100,000 histories will provide answers to most of the relevant questions about human sex behavior. It probably will.

One of the basic findings which Kinsey recognizes and which colors all of his presentation is concerned with the relationship existing between socio-educational status and sex behavior. Kinsey expresses it as follows.

> The data . . . show that patterns of sexual behavior may be strikingly different for the different social levels that exist in the same city or town, and sometimes in immediately adjacent sections of a single community. The data show that divergences in a sexual pattern of social groups may be as great as those which the anthropologists have found between the sexual patterns of different racial groups in remote parts of the world. There is no American pattern of sexual behavior, but scores of patterns, each of which is confined to a particular segment of our society. Within each segment there are attitudes on sex and patterns of overt activity which are followed by a high proportion of the individuals in that group; and an understanding of the sexual mores of the American people as a whole is possible only through an understanding of the sexual patterns of all the constituent groups.

The educational level attained by the time an individual terminates his schooling proved to be the simplest and best defined means of recognizing social level. Social level is not necessarily controlled by the amount of schooling that an individual has had, but the amount of schooling is associated in a regular fashion with the more basic factors which determine the social level. The reality of these social and occupational levels was also shown by the fact that each group had sexual mores which were, to a degree, distinct from those of all other levels.

That male sex behavior patterns are largely innate and not greatly modified or modifiable by training and experience is not too far from previously held belief. That sex behavior and attitudes are highly correlated with the educational level (and presumably with the intelli-

gence) of the individual is a new viewpoint and one that of necessity will lead to reorientation of many present day theories or explanations in general psychology.

Much of the psychology of sex has been placed in the field of abnormal psychology. There is no good reason for this except that Freud emphasized the role of sexuality in psychopathological conditions. Kinsey objects to this system of classification.

> The term "abnormal" is applied in medical psychology to conditions which interfere with the physical well-being of a living body. In a social sense, the term might apply to sexual activities which cause social maladjustment. Such an application, however, involves subjective determinations of what is good personal living, or good social adjustment; and these things are not as readily determined as physiologic well-being in an organic body. It is not possible to insist that any departure from the sexual mores, or any participation in socially taboo activities, always, or even usually, involves a neurosis or psychosis, for the case histories abundantly demonstrate that most individuals who engage in tabooed activities make satisfactory social adjustments. There are, in actuality, few adult males who are particularly disturbed over their sexual histories. . . . Clinical subjects who have such unusual items in their histories often do present psychopathologies—that is why they have gone to clinics. But the presence of particular behavior, or the existence of a high rate, is not the abnormality which needs explanation. The real clinical problem is a discovery and treatment of the . . . conflicts which lead particular individuals to crack up whenever they depart from the averages or socially accepted customs, while millions of other persons embrace the very same behavior, and may have as high rates of activity, without personal or social disturbance.

Several of the concepts which grew out of psychoanalysis and which have gained wide usage come under scrutiny. Infantile sex activity is a fact. No evidence is found for the latent period. Mental conflicts and repressions related to sexuality are common and usually fully conscious. No evidence was found for a concept of the Oedipus Complex based on actual occurrence of incest. No essential relationship between paranoia and/or alcoholism and homosexuality was demonstrated. Homosexuality is a behavioral experience in the history of so many American men that it cannot be considered psychopathological. "Sublimation is so subtle, or so rare, as to constitute an academic possibility rather than a demonstrated actuality." Each of the foregoing statements is based on good and sufficient evidence. Certain incidental findings with respect to the relationship between frequency of sex outlet and the personality structure of the individual are reported which should provide a starting point for a new line of research in the psychology of personality.

This volume is such a gold mine of information, it is so provocative of thought and comment, so suggestive of plans of research that any ordinary review can do no more than underline a few of the findings. Fortunately the book itself is, within a fortnight after publication, in

the "best seller" class. It is one of the five or six most stimulating books that I have ever read.

CARNEY LANDIS.

Psychiatric Institute, Columbia University.

HARROWER, MOLLY R. (Ed.) *Training in clinical psychology: Transactions of the first conference.* New York: Josiah Macy, Jr. Foundation, 1947. Pp. 88.

This volume, containing the papers delivered by a group of eminent psychologists, social workers, and psychiatrists at the conference on training in clinical psychology held by the Josiah Macy, Jr. Foundation in New York on March 27 and 28, 1947, should be read carefully by everyone interested in training clinical psychologists. The psychological papers by Harrower, Jacobsen, Shakow, and Miller are uniformly excellent and exhibit a breadth of view and eclectic tolerance which nevertheless do not preclude some forceful and stimulating individual opinions. The inclusion of a long paper by a psychiatric social worker (Ethel Ginsburg) is particularly happy since this approach is too often neglected in our training programs.

The psychiatric papers are much less broad in their treatment and reflect a heavy psychoanalytic bias. While this reviewer is willing to admit the necessity of a thorough grounding in psychoanalytic theory if one is to understand the dynamics of personality, and to admit the value of a didactic analysis as part of such training, it is disturbing to see the current trend in some psychiatric circles to assume that Freudian psychoanalysis by itself is enough, and that the didactic analysis will suffice to answer all the clinician's questions. Psychoanalysis is but one of many approaches to personality, and the clinical psychologist, both as professional practitioner and as scholar, can ill afford to limit his thinking to a single facet of a complex problem.

This symposium is a nice example of the professional service that can be rendered by an alert foundation. The Macy people are to be congratulated upon it.

WILLIAM A. HUNT.

Northwestern University.

RICHARDS, T. W. *Modern clinical psychology.* New York: McGraw-Hill, 1946. Pp. xi+331.

The author who seeks to interpret to a diversely trained audience the vigorous, expanding and often perplexing field of clinical psychology faces a difficult task. This book on modern clinical psychology is addressed to college juniors with one year of general psychology, to prospective physicians, to personnel consultants, to psychiatrists, to "all who seek to supplement the intuitive knowledge of personality they

already have" (vii). It combines a detailed analysis of the clinician's job with an interpretation of the dynamics of abnormal behavior, organized within a psychoanalytic and psychosomatic framework. As a text for the first course in clinical psychology, the book suffers from a restricted scope and an unevenness of presentation; as an exposition of one modern point of view toward understanding behavior pathology it is logical and consistent.

Four introductory chapters define the professional position of the clinical psychologist and describe his attitudes and procedures in obtaining case history material and in conducting interviews. A fifth brief chapter interprets the purpose of physical examinations for patients. The remaining sections are organized around three aspects of personality which the clinical psychologist must appraise: motivation, capacity and control. These chapters, comprising roughly two-thirds of the book, include material on objective tests, mental deficiency, projective methods and adjustive techniques, as well as descriptions and interpretations of deviant behavior from anxiety state to the major psychoses. Throughout these sections liberal use is made of case material and the results of psychometric and projective procedures. Chapters on precipitation and predisposition in behavior pathology, and readjustment through psychotherapy, conclude the volume. An appendix presents the standard American Psychiatric Association nomenclature, a bibliography of 148 titles and a list of available relevant films.

In its interpretation of the clinical point of view and particularly of patient-clinician relationships, the book is commendable. There is an unwavering respect for the individual patient and a willingness to examine such subtle variables as the patient's anticipatory attitudes toward the clinician, and the clinician's role as projective stimulus, with the same seriousness as test scores are examined. There is a consistent effort to preserve the integrity of the patient through case materials; isolated symptoms, episodes or test scores seldom appear out of their behavioral context. Professional readers will approve the objective treatment of such controversial topics as hereditary predisposition, intelligence testing and the significance of diagnosing psychiatric syndromes. The author clearly has a wide acquaintance with the experimental literature in his field.

Certain shortcomings of the book arise partly from the author's adoption of one theoretical position and partly from his attempt to compress a wide range of topics into a brief space. The strongly psychoanalytic and psychosomatic flavor of the writing results in a more highly constricted and systematized account of clinical psychology than the present diversity and richness of the field warrant. An effort to do justice to the variety of psychometric and projective techniques in current use results alternately in a superficial treatment and a sophisti-

cated interpretation which assumes considerable clinical and statistical background in the reader. The repeated use of single-item analysis of Minnesota Multiphasic Inventory responses in most cases reported is open to question in view of the exclusively statistical identification of the differentiating items. In the absence of detailed consideration of the scoring and interpretation of the Rorschach and the Thematic Apperception Test, the beginning student must certainly consider the results obtained from these techniques almost magical. Clinicians working in the usual clinic team will find somewhat unrealistic the author's emphasis upon face-to-face interviewing as the outstanding method of psychotherapy.

As a presentation of one point of view toward clinical psychology in its relation to problems of behavior pathology in the adult patient, this book deserves the attention of those who train and practice in the field. As a text for use in clinical courses, the book assumes more background in clinical techniques than the student in the first course ordinarily has, but at the same time it omits the detailed analysis which would recommend the book for graduate instruction. Perhaps no book which attempts to combine a single theoretical viewpoint with a practical teaching approach can effectively interpret to a heterogeneous audience the complex field of modern clinical psychology.

ANN MAGARET.

The University of Wisconsin.

MASE, DARREL J. *Etiology of articulatory speech defects.* Teachers College, Columbia Univ., Contr. to Educ., No. 921. New York: Bureau of Publications, Teachers College, Columbia Univ., 1946. Pp. viii+85.

In few areas of applied psychology are more persistent efforts made to solve molar problems with molecular techniques than in the field of speech correction. While in recent years it has come to be recognized that more than neuro-muscular mechanisms is involved in the etiology of "nervous" speech disorders, there is still widespread belief that impaired ability in certain speech actones is responsible for the causation of functional articulatory defects.

Dr. Mase put this belief to experimental test by comparing speech defective and non-speech-defective children on six of the variables in which speech defective children are commonly thought to be inferior.

A sample of 53 fifth and sixth grade boys considered physically, intellectually, and emotional normal except for the possession of a functional, articulatory speech defect was compared with a non-speech-defective group matched for sex, racial background, mental age, intelligence quotient, academic achievement, and socio-economic status.

Measurements were made of auditory acuity, memory span, coordination of articulatory muscles, coordination of gross muscles,

rhythm and tonal memory, and auditory discrimination. Tests of articulatory muscle coordination and of auditory discrimination were devised and standardized by the author. The other functions were measured by standard tests.

No statistically significant difference was found between the speech defectives and their controls on any of the factors investigated. Only one difference, auditory acuity, consistently approached significance, and this difference averaged less than three decibels at threshold. The author comments in passing, however, that in the preliminary audiometric screening more than three times as many speech defective children were eliminated because of impaired hearing than non-speech-defective children.

The generally negative findings, the author stresses, do not mean that the variables studied could not have been related to the *onset* of the speech defect, but simply that they were not now present to a significantly different degree in the two groups studied.

A few criticisms might be made of this study. First, teachers reported only 32 speech defective boys in a population of 871, but the author in a brief examination of 581 children from the same population screened out 193 as speech defective, and this number did not include "many cases of foreign accent." The narrow limits for speech normality suggested by these data are in marked contrast to the wide limits observed for intellectual and physical normality. The matter is of some importance since the author proposed to discover if the assumed causative factors were present "long after the speech defects first became noticeable"; yet, by his own account, most of the defects were not recognized prior to his examination, and data as to time of onset are lacking.

Secondly, it is generally agreed by workers in audition that attempts to measure auditory acuity in non-sound-proofed environments are largely futile. Examination of Dr. Mase's data in which it is shown that every child but one had a hearing loss, and that no child tested above the zero level, suggests that the author may have been measuring the variations in the sound level of the environment rather than the auditory acuity of his subjects.

Despite these relatively minor criticisms, Dr. Mase's study is a valuable and needed piece of work. Aside from its value for clinical workers, it puts to experimental test some widely held beliefs and is an important contribution to the beginnings of a science of speech correction.

LEE MEYERSON.

Vassar College.

SADLER, W. S. *Mental mischief and emotional conflicts: psychiatry and psychology in plain English.* St. Louis: C. V. Mosby, 1947. Pp. 396.

This book purports to present the *Gospel of Health*, and to discuss

the neuroses and "those borderline disturbances of human personality which exist out in the 'no man's land' of mental hygiene between the neuroses and insanities." Thirty-one of the 34 chapters present some pathological symptom. A bibliography of 34 references is given, but not over five of them would generally be considered important contributions to psychology or psychiatry.

A serious criticism of the book is its lack of documentation; it does not contain a single citation. Another weakness is the anecdotal character of the discussion, which entirely confuses fact and opinion, and often really gives neither fact nor justifiable opinion.

To many readers the following illustrations will not recommend the book: (1) There are six principal human drives, viz., an urge for life, for play, sex, worship, a social urge, and a sense of humor; (2) "Hereditary predispositions are at the bottom of most neurotic difficulties . . . "; and (3) " . . . the full-fledged homoerotic . . . comes into the world with a male body and . . . with a female attitude of mind and emotions. . . . "

While purporting to draw on contemporary psychology, the book mentions only three living American psychologists: Allport, Köhler, and Rhine. Of well-known psychiatrists, only Freud is mentioned. Other omissions are unfortunate. Mental hygiene and psychotherapy are discussed together in nine pages, while an equal amount of space is devoted to the value of faith and religion.

In general the book can do little good. The trained reader would recognize its inadequacies; the unsophisticated might believe some of the debatable information presented. Unfortunately this sort of "popular" book on psychotherapy is becoming increasingly common, and may, we feel, cause real harm by diverting maladjusted persons away from adequate psychotherapy.

WILLIAM U. SNYDER.

The Pennsylvania State College.

MERRILL, MAUDE A. *Problems of child delinquency.* New York: Houghton Mifflin, 1947. Pp. xxiii+403.

A problem as prolific of research articles by psychologists as juvenile delinquency has generally produced its complement of rationalizations of the journal literature commonly known as textbooks. Concerning juvenile delinquency, however, few texts other than interpretations by sociologists have appeared. The present volume is at once a research report and an integration of significant literature from the psychological viewpoint. It considers the delinquent girl as well as the delinquent boy.

Although written in non-technical language, using simple statistical manipulations, and containing many illustrative case histories, this work should not be underestimated. It considers important and far from simple problems of motivation and of evaluation of environmental stress and conduct responses to stress. It treats such concepts as frus-

tration tolerance, integration of motives, needs and drives, and the personality as dynamic in more than the cursory manner such topics frequently receive in "popular" books. The author very effectively presents the whole child without rhapsodizing about "wholeness."

The framework of this text is the report of a study of 300 unselected juvenile delinquents, boys and girls, from a rural county of California and a control group of non-delinquent school children matched for age, sex, and locality, and a follow-up study on available cases made four to six years after the original study. A variety of psychological measures, including "projective techniques" were used. Comparisons are presented simply and clearly in 43 tables running throughout the 319 pages of text. There is also an extensive appendix, which includes a rating technique for classifying and summarizing data obtained from standardized interviews.

Each chapter presents an orientation to the problem to be treated in the chapter (whether school adjustment, intelligence, motivation, interests and attitudes, etc.), the pertinent comparisons of the delinquent and nondelinquent subjects of the study and, generally, one or more detailed "case records" to illustrate the major point or points made in the chapter. Skillfully woven into the discussion are references to the best research and theoretical literature, all conveniently and accurately footnoted.

In this reviewer's opinion, the chapters describing measuring instruments and techniques which have been used in various studies of delinquents, and the discussion of factors in after-treatment adjustment, are particularly well handled. Of merit is the criticism made of reappearance in court as a simple criterion of treatment failure: "The children's court can more profitably think of itself in terms of the parental relationship in which it was originally conceived and which does not count its failures in terms of a continuing relationship" (p. 273). The author criticizes the Gluecks' conclusions concerning the persistence of delinquent behavior in terms of the inadequacy of the above criterion and in terms of the fact that their delinquents were originally clinically screened as difficult cases.

Of equal importance is the emphasis on the relevance of delinquent acts to the needs of the individual child. Delinquent behavior is, then, considered to be "purposive." The author rejects the hypotheses that there is a delinquent type of child and that there exist patterns of circumstances invariably associated with delinquency.

Wholly apart from the significance of a well-designed and carefully executed study (which serves principally to confirm other research data) this text makes an important contribution in the synthesis and interpretations of literature. As such, it could only have been accomplished by as skillful and experienced a student of child behavior as the author.

It is to be hoped that sociologists, who most frequently teach the

college courses on delinquency, will appreciate the significance of this book and use it along with the commonly used sociological texts on crime and delinquency.

DALE B. HARRIS.

University of Minnesota.

JERSILD, ARTHUR T. *Child psychology.* (3rd Ed.) New York. Prentice-Hall, 1947. Pp. vi+623.

As Dr. Jersild indicates in the Preface to this edition, he "tried to bring the 1940 version up to date, and . . . to remedy certain shortcomings in the old text while preserving qualities that were well received." These are reflected in " . . . more attention . . . to the question as to what a child's overt behavior reveals about his private thoughts and feelings," and "more consideration . . . to the influence of the cultural environment and the attitudes of others on a child's behavior and adjustment."

The formal organization of the book, too, is somewhat changed. New chapter titles, more chapter subdivisions, re-arrangements in sequence, reduction of the number of chapters assigned to some subjects and increase in those assigned to others, enhancement of the material presented in connection with each of the subjects treated, and improvements in the style and manner of presentation of subject matter are featured in the new volume.

The research literature cited and the bibliographies have been enlarged and verily brought up-to-date. Not only have numerous references to the literature which appeared subsequent to the preparation of the second edition been added, but also many references to earlier literature, not cited in the second edition, have been included, thus enhancing immeasurably both the evidence presented and the lists themselves. Yet, despite the increase in the references cited their integration with the general content has been improved.

As Jersild states in the Preface, "More prominence has been given to principles and generalizations . . . " than in the earlier editions, and "more adequate account" has been taken "of the interplay between forces in the growing organism and the impact of various aspects of development upon each other." In short, the author presents a really new edition, which those who have been using Dr. Jersild's book will welcome and those who have not done so will want to consider, if their approach in the teaching of child psychology is through the study of reported research and by way of the traditional, topical treatment.

JACOB I. HARTSTEIN.

Long Island University.

AXLINE, VIRGINIA MAE. *Play therapy: The inner dynamics of childhood.* Boston: Houghton Mifflin, 1947. Pp. xii+379.

Most psychologists will agree with Shaffer's recent statement that

"The major problem of psychotherapy today is its improvement through research. Schools and doctrines, conceived primarily to persuade and to teach, are unlikely to supply us with the basis for this improvement."

Research is not the only problem connected with psychotherapy, however. The same psychologists would also agree, but perhaps less enthusiastically and with less interest, that parents and teachers need motivation and practice in establishing favorable learning conditions for the children under their guidance—conditions in which the children can really practice the making of independent choices and can discover the consequences of their actions in a secure and emotionally comfortable atmosphere. Whether the creating of such conditions is a form of psychotherapy, technically speaking, it is undoubtedly closely related to it. Contemporary American culture does not always place a premium on the establishment of this kind of child environment. If parents and teachers are to be pressed in this direction, persuasion and teaching by example must be provided, and if the teachings are mildly tinged with inspiration and emotionally toned values, the effects will be better rather than worse.

Miss Axline's book will irritate those whose main goals are represented by Dr. Shaffer's statement. The only reference cited in the entire volume is Carl Rogers' *Counseling and Psychotherapy*. No evidence is given for any of the numerous categorical statements about principles of psychotherapy or the structure of personality. The book abounds with phrases such as "it seems as though," "it may have been that," "another factor that the writer believes to be important," "it seems unwise." Before and after descriptions of case material are equally cavalier; scant reference is made to the amount of disturbance shown by children before treatment, and little indication is given as to how much and in what ways the treatment modified behavior. Although the Rogers group has proved unusually fertile as a source of research in the field of psychotherapy, none of these published studies is mentioned. The whole aim of the book appears to be to persuade and teach, and to do this without giving evidence, other than exemplary material, for the viewpoint expressed.

Taken for what it is, on the other hand, the book makes fascinating reading. Miss Axline's own style is lively and pictorial. She includes a tremendous amount of verbatim material from therapy sessions, all very lively. One complete group therapy record, covering eight sessions, requires over fifty well-earned pages of the book. Not only do the five boys in the group stand out as vivid and real children, but the description leaves the reader with a conviction that the youngsters had constructive emotional experiences during the play sessions. The therapist claimed no more. Many other case examples also illustrate, both directly and by implication, the integration of non-directive therapy and principles of progressive education. The repeated emphasis on self-

initiative and taking of responsibility will be illuminating to all whose work involves social engineering with children. The chapter on practical schoolroom applications of non-directive principles is especially good.

Surprisingly, there is no similar section on parent-child relationships in the home. Is this because the Rogers people shy off from the emotional tie between parent and child much as they do from personal emotion between therapist and patient? They always seem to avoid rather than to face squarely up to relationships of love and affection. Parents as well as therapists and teachers should be concerned with "being alert to recognize the *feelings* the child is expressing," "accepting the child exactly as he is" and "maintaining a deep respect for the child's ability to solve his own problems if given an opportunity to do so" (p. 75)—three of the eight "basic principles" of non-directive counselling.

For students of child psychology, for teachers, and for parents too in spite of its omissions, this book may be safely recommended as one of the several missionary approaches to the fostering of sound personality growth in children. The book communicates its ideas effectively; any intelligent lay adult can appreciate the material. It is simple, straightforward, and should have much easier application to actual practice than more complex notions deriving from psychoanalytic doctrine. Furthermore, it is difficult to see how any serious harm could be done to any child by the views presented.

From the standpoint of technical psychotherapy, however, one serious question must be raised. This book suggests no limitations on the use of its described procedures. It is probable that with seriously disturbed children thorough and effective psychotherapy cannot be done by non-directive methods. It would be unfortunate if this book led teachers to believe that they could deal with any problem no matter how serious. When emotionally sick children are encountered in the clinic or the hospital, a more eclectic and less denominational approach than that of the Rogers school is needed. There is no question but that many children will be helped by the fervor of the non-directional therapist; if members of the Rogers group would state as clearly as they can at present *which* children will probably be helped and *which* will need some other form of treatment, the non-directive method would be received by psychologists with a great deal more sympathy than is now the case.

PAULINE SNEDDEN SEARS.

State University of Iowa.

LE CRON, L. M., AND BORDEAUX, J. *Hypnotism today.* New York: Grune & Stratton, 1947. Pp. ix+278.

This book is described as the first presentation of the entire subject of hypnosis to include recent experimental work. The authors—both consulting psychologists—have as their aim the demonstration that

hypnosis is a true branch of psychology. The book consists of two sections: Part I is concerned with hypnotism and suggestion, Part II with hypnotherapy.

In Part I the traditional problems of hypnosis are considered: technics of induction, phenomena of the trance state, tests of susceptibility, autohypnosis, etc. The reviewer's main criticism is that numerous statement are made without supporting data. Thus the importance of operator prestige and indirect suggestion, denied by many workers on the basis of empirical data, is emphasized throughout the book without any attempt at substantiation or at evaluation of pertinent literature. The question of susceptibility has always been a difficult problem. The treatment in this book is not particularly helpful. For example, it is not always clear whether statements made about the susceptibility of "hysterics," "sleep walkers," "bullheaded individuals," "Hebrews," "Latins," etc. are based on fact or speculation. Although the authors state that many of their conclusions are based on "extensive observation by experts," it is not very convincing to meet these observations in the form of such statements as, "*most* hypnotists *usually* find relatives . . . *somewhat* intractable" (81) (italics are the reviewer's). Other objections were: the loose use of the terms suggestion, indirect suggestion and hypnosis, the reduction of social psychology to a mild form of hypnotism, and the error in fact in reporting Esdailes's use of hypnotic anesthesia as uniformly successful. On the positive side the authors may be credited with providing those interested in using hypnosis with many practical procedural technics.

In the little over 100 pages comprising Part II the authors present a condensed survey of sections of the fields of general and abnormal psychology, psychiatry, psychoanalysis, psychosomatic medicine and mental hygiene, as background for the use of hypnotherapy. For the individual with training the survey is of little value, and for the individual without training, too sketchy. Le Cron and Bordeaux believe that the use of hypnosis, together with special features of psychoanalysis and psychotherapy, offer the best hope for the brief and inexpensive treatment of neurotics. This section in which the maximum contribution of consulting psychologists might be expected is disappointing. Discussion of clinical applications of hypnosis occupies less than 60 pages and incomplete reference is made to only seven of their own cases. Furthermore their wide coverage of the possible adjuvant and direct uses of hypnosis precludes more than a sketchy discussion on any one topic.

The reviewer believes that the consultant can make significant contributions to the field of hypnosis, but he is not convinced that the authors of *Hypnotism Today* have made such a contribution.

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TIFFIN, JOSEPH. *Industrial psychology.* (2nd Ed.) New York: Prentice-Hall, 1947. Pp. xxi+553.

The publication of a second edition of a widely used textbook leads naturally to comparing the new with the original. Those who are familiar with the first edition will find no radical change either in organization or emphasis in the second edition. The author has added new material to strengthen his treatment of the topics of employee selection and industrial training. He has added little to the sections on fatigue, accidents, or worker morale.

Of the two new chapters appearing for the first time in this edition, the one dealing with the employment interview (Chapter 2) is relatively superficial in comparison with treatment of this subject by other textbook writers in this field. The other new chapter, "Wages and Job Evaluation" (Chapter 11), is based primarily on the published research of Lawshe and his associates. Its description of a simpler technique of job evaluation than has been used previously in industry will be of value to the industrial practitioner.

Tiffin has added to his earlier material on industrial training a description of job analysis for training purposes (pp. 268–272). This material and the material on industrial merit ratings (Chapter 10) have definite practical values.

Again Tiffin has allocated more space to the topic of industrial vision than to any other single topic. Vision is important to industrial efficiency, but it is doubtful that it is more important to either the student or the practitioner than, for example, is the problem of workers' attitudes and morale. Tiffin has devoted almost twice as much space to vision as he has allocated to this problem. This emphasis may reflect the absence of pertinent data on workers' attitudes as contrasted with an abundance of data on industrial vision. Or it may reflect the author's special interest in the latter area. It certainly does not reflect the relative importance of these problems in industry.

The author's style is that which so many psychologists have acquired in depersonalizing articles for scientific journals. It will not transmit to the reader the dynamic interplay of man and machine in an industrial society.

The student will derive from the text no systematic point of view or frame of reference against which to evaluate the research data marshalled throughout the text. Perhaps the field of industrial psychology is not yet adequately structured for the philosophical orientation of the student and practitioner. The author, however, would have added stature to his text if both by example and precept he had made a more definite effort to inculcate into the reader a critical attitude toward alleged research in industrial psychology.

The second edition of *Industrial Psychology* will be used widely in

college classrooms. It even will find its way to the desk of the industrial practitioner. For, in comparison with other texts in this field, Tiffin's book is superior to most, if not all, of the texts currently available.

WILLIAM MCGEHEE.
Fieldcrest Mills, Division of Marshall Field & Company.

ZUNINI, GIORGIO. *Animali e uomo visti da uno psicologo* (Animals and man seen by a psychologist.) Milan: Societa Editrice "Vita e Pensiero," 1947. Pp. xi+293. Lire 300.

This book forms part of a series edited by Father Agostino Gemelli which have come out of the newly-established Laboratory of Experimental Psychology of the Catholic University. The grand object of this series, as explained by Gemelli in his introduction, is to free psychology from the province of philosophy and to show the relationship of man to biology.

This announced attempt to liberate psychology from metaphyscial speculation does not quite come off. The resulting book forms a peculiar potpourri, nothing quite like it having ever been seen by this reviewer. Writing in an ingratiating, humorous, semi-biographic style, the author begins with an account of his early experiences with minnows at the Zoological Institute at Monoco under Karl von Frasch, and proceeds to discuss the peculiar behavior of these little fishes on whose brains he operated. Zunini advances to a long, charming but not particularly valuable discussion of his dog, and then advances in the most elementary fashion to a prosaic discussion of instinct and development. Finally he comes to involved philosophical speculations concerning causes and ends in biology thus discussing that which was expressly to be avoided. The author at times does something which the reader can hardly help but sympathize with: he commiserates with the paper on which he is writing for all the blots and erasures he is making due to his confusion, and finally concludes the first section of the book with the thought that he would have done better to have let the paper remain in his writing box.

The second half of the book, which concerns the topic of man, is not as well done. Beginning boldly with the topic of sexuality, he concludes that human love is a mysterious thing, for while animals are driven by sexual impulses, there is more to love in man than sex. The chapter on personality is rather well done, covering in a pedestrian fashion the writings of standard authors in the field. Psychoanalysis is treated with fearful respect, and the final hesitant evaluation is that psychoanalysis introduced a dynamic concept of personality. Again the section ends with philosophical speculations: man has not met his destiny; he is the slave of science; and the functions of psychology are to free man from his errors and to help him to regain his sense of personal worth.

This uneven, peculiarly disjointed book tells more, perhaps, about the status of psychology in Italy than about animals and man. It is not too

clear to whom this volume is addressed, but the reader cannot help but be impressed at the lack of security on the part of the author.

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SHERMAN, MANDEL. *Psychology for nurses.* New York: Longmans, Green, 1947. Pp. xiii+237. $2.75.

This is a brief survey of the entire field of psychology from sensory stimuli to personality and neurosis. Its organization as indicated by the table of contents is excellent. Only 23 pages are devoted to sensory processes and perception, while about 100 pages deal with the more applicable cognitive processes and another 100 pages describe normal and abnormal dynamics. However, the actual content of most of these well proportioned chapters is disappointing. The impression throughout is that the author made haste to put down as much as possible in limited space without regard for the problem of making it understandable and interesting to the student. It would have been far better to have made fewer statements and made those more memorable.

There are only eight figures occupying a total of about three pages. Too many terms are used without explanation: memory span, peripherally or cortically aroused experience, projection areas of the brain, regressive, unsolved parental fixation, to mention only a few. And some terms are used in an unusual or non-technical sense. "Insight" seems to mean implicit trial-and-error learning or perhaps any kind of implicit manipulation of images or concepts. "Span of attention" refers to the length of time the subject can attend to one general topic such as a lecture. "Extrasensory" is used in the following manner in explaining affect: ". . . injurious conditions are affectively unpleasant, whereas those extrasensory experiences that tend to maintain the equilibrium of the individual are pleasant."

Throughout the book the reader is given a feeling of haste and carelessness both of statement and of argument which cannot be adequately exemplified in the space of a review. Chimpanzees are called monkeys. Allport is credited with having "classified persons into the *ascendant* and *submissive* types." The rejected child is said to be "affectionately deprived." The stammerer is supposed to be "given insight into the fact that no one considers his speech difficulty abnormal or undesirable." And the student is told without any explanation that "various substitute sex satisfactions develop, such as thumb sucking."

Each such minor inaccuracy or inadequacy is perhaps negligible in itself. However, it is unfortunate that they, together with the constant need for greater embellishment of fewer facts, should characterize the book.

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JOAD, C. E. M. *How our minds work.* New York: Philosophical Library, 1947. Pp. 116.

The climate of the book is reflected in the statement, " . . . we cannot explain the facts of psychology without bringing in the mind" (p. 13). Later (p. 16) mind is defined as " . . . something which is not material, which is not therefore part of the body, and which does not obey the laws of chemistry and physics which the body obeys." Since the mind-body problem is said to be " . . . the fundamental problem . . . upon which modern psychological controversy very largely turns" (p. 9), it is perhaps not surprising to hear the author state (p. 2), " . . . in psychology there are no facts which everybody agrees to be facts."

Briefly, psychology is offered a choice between a naive materialism (complete with hydraulic analogies of the nervous system) and an equally naive mentalism and interactionsim which is strongly defended. Nowhere is it suggested that as a science psychology need not, and commonly does not, concern itself with the metaphysical problem of mind and body, but that it is very busy with studies of observable inter-relationships between many processes such as attitudes, purposes, emotional needs, perceptions, glandular secretions, neural dynamics, social factors, without pausing for signals at some indefinable boundary between mind and matter.

Despite the author's reference to his book as an "outline of modern psychology," it may then be safely said that the book is not psychology as the psychologist now uses the term. Nor is it modern in the sense of presenting the recent advances and most sophisticated accomplishments in the field. William James is belabored for his materialistic theory of emotions (made to include anachronistically a reference to adrenal activity). McDougall has the latest word on instincts. Watson comes in for a belated drubbing. Faculty psychology is evaluated. The eight pages devoted to a superficial discussion of Freud and the unconscious add little beyond 1914.

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